

FORESTRY

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FORESTERS OF GREAT BRITAIN

Edited by C. W. SCOTT

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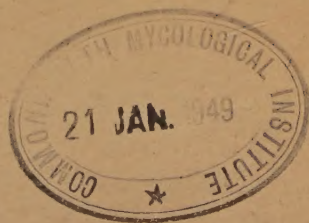
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THE SOCIETY AND ITS JOURNAL

THE IMPORTANCE OF FORESTRY is being realized more and more in Great Britain. The number of foresters is increasing steadily, and a forestry profession is gradually being built up. It is intended that this Society should be representative of the profession. Those who are not engaged in the practice of forestry or the allied sciences are cordially invited to join the Society as Ordinary Members.

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THE SOCIETY'S JOURNAL, called *Forestry*, is usually published twice a year, in June and December. It provides a means for the publication of the results of practice and research both in the growing of timber and in its utilization, including such basic sciences as forest physiology and ecology, forest soils, wood structure, and timber physics, and allied sciences such as forest entomology and forest mycology.

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SOCIETY'S MEDAL. For the rules concerning the award of this Medal see vol. xx, pp. 80-1.

BIRDS AND THE FORESTER

By W. L. TAYLOR, C.B.E.

TWO very interesting papers on the importance of bird life to the forester have recently been brought to my notice by the courtesy of the Commonwealth Forestry Bureau. One from Sweden, entitled 'Forestry and Forest Birds' (1), and the other from Poland, under the title of 'The Role of Birds in Silviculture' (2). Both these papers indicate a growing interest in forest bird populations in European forestry and the desirability of encouraging all species but the very few now considered to be harmful. The need for forest officers and foresters to be biologically minded in this regard and for the further study of forest ornithology is pointedly stressed.

The writers advocate the encouragement of all kinds of birds other than those of which there is full proof of their harmfulness. It is pointed out that no complete investigation of birds' diets has yet been made, on which to base a distinction between useful and other species (1). It is accepted that birds have a part to play in maintaining the natural equilibrium of forest associations and that their help in the control of insect pests is important. Even the hawks, and certainly the owls, fulfil a useful purpose in keeping down vermin, although the statement that the sparrow-hawk should not be destroyed as it attacks only weak, crippled, and sick birds (2) is hardly borne out by observation of this hawk in British woods. The species noted as certainly injurious in the forest community are the crows, magpies, and jays.

Conditions influencing bird-life in the forest are usually subject to wide local and seasonal variation, and there is little that the forester can do about it in the course of his silvicultural operations, which often result in no more than a move of a few hundred yards for the birds to regain their chosen environment; for instance the operation of thinning may hardly be noticeable in its effects. As Bromée-Skuncke says, 'The natural equilibrium, if it really exists, is a very fluid one. . . . Nature's symphony, though usually harmonious, is played in many different keys' (1).

Both papers stress the importance of insectivorous birds although neither appears to mention the fact that most of the seed-eaters feed their nestlings largely if not, in some cases, exclusively on insect food. Especially are the hole-nesting species important to the forester, a fact that does not altogether march with some of the concepts of systematic forestry. It is desirable to leave at least some hollow trees standing, and there has long been an instruction on this point in the Swedish Crown Forests (1). In managed forests, however, the tendency is for defective trees to be cut out, in which circumstances the birds must be provided with artificial nesting-boxes. Excessive clearings of shrubs and bushes from the under-story is another wrong practice, and harm may result from over-draining. Instructions against each of these two common practices are also in force in Sweden.

Bromée-Skuncke and Koehler are at one in their advocacy of the provision of a sufficient number of nesting-boxes. The former lists sixteen species of hole-nesters common in the Swedish forests. It is believed that many insect epidemics in these forests have been kept within reasonable limits by the small insect-eating birds, particularly the hole-nesters, which are known to take the oak-leaf roller and other pests in large numbers. Invaluable service in the forest is attributed to the small bird populations by all experts on the fauna of Swedish forests.

The Domains Board in Sweden (the State Forest Administration) has put up over 46,000 nesting-boxes in State forests in the past 14 years; and the work is actively advocated in Poland. Boxes have also been put up in some of the privately owned forests. Some very interesting notes, based on 5 years' study, are quoted (1). It is a first principle that the boxes should be so placed that their inhabitants can quickly reach the shelter of the undergrowth in case of need. Merely putting up boxes in a given stand is scarcely enough to attract hole-nesters. Aiding the birds means putting the boxes in situations in which the birds feel at home. The younger hardwoods and mixed stands, preferably moist and with an under-story of bushes or underwood, are decidedly better than coniferous and dry woods. The older conifer stands, especially Scots pine (*Pinus sylvestris* L.), are particularly poor in bird life, even where bark and shoot beetles are abundant. The provision of drinking-pans is a help (2).

It is noted that in the larger virgin forest areas of Sweden, where fellings are prohibited, the population of small birds is scanty. Nesting-boxes on bare, open stems are not favoured, and positions that are heavily shaded, as under the dense branching of spruces, are disliked. The statement that low-placed boxes are preferred does not, however, bear out experience gained in the Forest of Dean. No particular importance is placed upon aspect, provided the entrance hole is sheltered from the prevailing rain-bearing wind and is not open to direct sun-scorch. Neither does it appear that the birds are very particular about the type of box, if natural nesting-places are few.

Swedish experience (1) indicates that nesting-boxes should not be fixed close to branches which may give foothold to predators. They are usually sited at least 20 metres apart. No loose material should be put in the boxes; smaller rather than larger stems should be chosen for the artificial nesting-places; and the most suitable time of year to put up the boxes is in late summer and autumn. Finally, the birds should not have unnecessarily large boxes; the boxes must be dry; and they should be cleaned out yearly to avoid the harbouring of insects, and for general hygiene.

It is of interest to British foresters to learn that nesting-boxes made of sheet-metal are effective. When first introduced, in Sweden, they were unpopular, but they have been found to compete successfully with wooden types. Sawn timber, round hardwood or softwood, sheet-metal, and plastics are all used in construction, although experience with the last-mentioned material is limited, so far. Of 2,552 metal boxes put up, no less than 1,778, or 70 per cent., were occupied; of 108 Bakelite boxes 74 per cent. were occupied; while of 1,988

wooden types the percentage occupied was not more than 35, some 14 per cent. being damaged by woodpeckers.

In Sweden the most assiduous box-user has been the pied flycatcher (*Muscicapa atricapilla*). Next come the tits (*Parus* spp.), although, in Nörrland, redstarts (*Phoenicurus phoenicurus*) have nested as frequently as tit-mice. As far as experiments have gone in Great Britain (Forest of Dean) the pied flycatcher has also proved the easiest bird to attract. Starlings (*Sternus vulgaris*) have been found hard to entice into forest boxes (1).

An improved type of metal nesting-box has been devised by Bromée-Skuncke, giving even better results than those quoted above. This box might well prove satisfactory in British woodlands.

LITERATURE REFERENCES.

- (1) 'Forestry and Forest Birds, with special reference to the Hole-building Species', by F. Bromée-Skuncke, *Svenska Skogs Fören. Tidskr.* xlv, (3), 1946.
- (2) 'The Role of Birds in Silviculture', by N. Koehler, *Ulotk, Wydaw. pop. Inst. Bad Lésn.* No. 21, 1947.

A BASIS FOR FIXING CONTROLLED PRICES OF ROUND CONIFEROUS TIMBER

BY W. E. HILEY

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I. INTRODUCTION AND SUMMARY.

1. *Introduction.*

CONTROLLED prices for timber, both standing and converted, were introduced at the beginning of the Second World War. This control served to prevent prices from soaring and was an integral part of the system of State planning of the supply and distribution of timber, which was universally acknowledged as a vital necessity with any commodity which was essential for the prosecution of the war and, at the same time, was liable to become very scarce. It is nearly 3 years since hostilities ended, but timber is still scarce and proves to be as essential for reconstruction as it was for war. So control of prices has continued and is likely to continue for many years. Under a planned economy it may be continued indefinitely and it may be used not only to prevent producers of timber from making undue profits but, by assuring minimum prices, to support the forest industry during world depressions and to encourage woodland cultivation. Under the Dedication Scheme sanctions are applied to forest owners who do not manage their woods with reasonable efficiency; an effort should therefore be made to assure a fair profit for those who cultivate timber with energy and resource.

The concept of a fair profit is a necessary basis for the control of the price of any commodity which is produced under conditions of private enterprise. If producers cannot make a profit, or if the profit is very small, production will gradually cease; if the profit is too large, consumers will be unfairly treated. Even when prices are fixed, a competent manager will make larger profits than an incompetent manager; and, apart from competence, the profit from tree cultivation will be affected by fertility of soil, nearness to markets, and other factors. It would be impracticable to fix prices in such a way that forestry would be equally profitable over a wide range of varying conditions and, in practice, we have to be satisfied with prices which allow of a reasonable profit under conditions which are rather less favourable than the average.

Profit in farming, as in forestry, is affected by fertility of soil, nearness to markets, and competence; and the prices of agricultural products have been fixed in a manner which has given fairly general satisfaction. But in forestry there is an additional complication; the period of production is so long that it is almost impossible to trace the costs which have been incurred in growing a tree from the sowing of the seed to the felling of the timber. Even if complete cost accounts were available, the value of the unit in which they are measured,

namely the pound sterling, has changed so frequently and so profoundly that a summation of these units would have very little meaning.

In the present paper an attempt is made to find a basis on which fair prices may be computed. No method which can be devised will be above criticism; all that is claimed for this method is that it is an honest attempt to meet the very real difficulties which are inherent in the subject.

2. Summary.

(a) The *principles* involved in determining fair controlled prices of standing timber are:

First. They should allow of the remunerative working of a normal forest on a basis of sustained yield. In working such a normal forest the timber stocking remains constant from year to year. So any excess of income over expenditure in a year is derived from the increment during that year and is justly regarded as profit. Prices should not be so low that forestry cannot be conducted profitably.

Second. The net annual profit on a normal forest should represent a reasonable rate of interest on the actual cost of creating such a normal forest.

The second principle involves the concept of interest on capital in two respects. Firstly, money is sunk in making a forest; the amount involved is increased year by year as more money is expended, and the total is reduced by any net income which is derived from thinnings. The period over which this money has been invested varies from 1 to 100 years in the case of Scots pine (*Pinus sylvestris* L.), to 1 to 50 years in the case of Douglas fir (*Pseudotsuga taxifolia* Brit.). A rate of 3 per cent. has been used in this calculation, and 3 per cent. compound interest has been charged in computing the cost of forming a normal forest. It is unlikely that, over the last 100 years, a woodland owner could have borrowed money at an average rate of 3 per cent., but it may be noted that 3 per cent. is the rate at which the Government is prepared to loan money for forest development.

Secondly, the net profit earned annually from working the normal forest is expressed as a rate of simple interest on the cost value of the normal forest. If an owner borrowed money at 3 per cent. to make his normal forest, and if his subsequent net income only represented 3 per cent. on the cost of the normal forest, then this income would only be sufficient to meet the interest on his debt. Only if he subsequently makes more than 3 per cent. on the completed normal forest does he earn a profit on his enterprise. The rate of 4 per cent. has, therefore, been adopted for this rate of interest.

(b) *The net annual return from a normal forest* is the difference between the gross receipts and the gross expenditure.

The gross receipts have been calculated from yield-table volumes and maximum controlled prices.

The gross expenditure has been calculated from the number of men required to maintain and work a normal forest, the minimum agricultural wage, and an

allowance for purchases and overheads of 30 per cent., over and above the product of number of men, multiplied by minimum wage.

The results of these calculations are set out in Table III. There is a net loss on all qualities of Scots pine and on the lower qualities of European larch (*Larix decidua* Mill.) and Norway spruce (*Picea abies* Karst.) There is a profit on all qualities of Douglas fir and on the higher qualities of European larch and Norway spruce.

(c) *The cost of forming a normal forest* is the sum of the costs of its constituent parts. Although forestry text-books contain formulae for calculating the cost of a normal forest, these formulae are constructed on the basis of fixed wages and prices. They are, therefore, inapplicable to the present investigation. It would be very laborious to calculate the cost to date of 100 acres of pine forest of which 1 acre had been planted in each of the last 100 years. I have, instead, estimated the cost of 10 acres planted in each of the years 1853, 1863, 1873, . . . 1943 and have assumed that thinnings were taken at decennial intervals.

An average cost of each pertinent operation, with the present minimum wage of 90s. a week, has been worked out. The costs of these operations at each past decennial period have been calculated by multiplying present costs by the wage index at that period and dividing by 100. The wage indices have been taken from MacGregor's 'Labour Costs in English Forestry since 1824' (6).

The present receipts from thinnings have been estimated from money yield tables constructed from the *Forestry Commission* (volume) *Yield Tables* (3) with present prices. Past receipts from thinnings have been calculated from present receipts by reducing them for each decennial period in accordance with the wage index.

The costs and returns for the plantation made in each decennium have been brought forward to the present time with compound interest at 3 per cent.

The cost of the normal forest is the sum of the costs of these separate plantations.

In this manner cost values have been worked out for normal forests of 100 acres each, on second-quality sites, of (1) Scots pine on a 100-year rotation, (2) European larch on an 80-year, (3) Norway spruce on a 70-year, and (4) Douglas fir on a 50-year rotation.

The cost of each of these forests is shown in Table IV.

(d) *Results.* In none of these cases does the calculated net profit from a normal forest represent a return of 4 per cent. on the calculated cost of forming the normal forest. To achieve this rate of interest it would be necessary to raise the price of Scots pine by 147 per cent., European larch by 44 per cent., Norway spruce by 42 per cent., and Douglas fir by 10 per cent. After making a necessary adjustment it is calculated that a general rise in prices of 42 per cent. would bring the average return on second-quality plantations up to 4 per cent. on the invested capital. The conclusion reached in this paper is that a rise of 42 per cent. in the controlled prices of round coniferous timber at stump is required in order to make the cultivation of forests reasonably profitable.

A rise in wages should be followed by a rise in timber prices; but the rise in prices need not be proportional to the rise in wages. It is calculated that if, after prices had been raised by 42 per cent., there was an increase of 10 per cent. in the minimum agricultural wage, then prices should be raised by a further 6·7 per cent. above the new level in order to allow a forester to earn the same profit as before.

II. PRINCIPLES INVOLVED IN FIXING PRICES.

The following principles are involved in the method which is here advanced.

(a) *Prices must be such that the sale of standing or felled timber will yield a reasonable return on capital invested.* The rate of compound interest which can be earned on the capital invested in a plantation is calculated by means of the well-known Faustmann formula, namely:

$$S = \frac{Yr + Ta \times 1 \cdot 0p^{r-a} + Tb \times 1 \cdot 0p^{r-b} \dots + Tq \times 1 \cdot 0p^{r-q} - C \times 1 \cdot 0p^r}{1 \cdot 0p^r - 1} - \frac{e}{\cdot 0p^r},$$

where S is the value of 1 acre of land,

Yr is the net value of the final yield on 1 acre,

$Ta, Tb, \dots Tq$ are the net values of thinnings in the years $a, b, \dots q$,

C is the cost of establishing 1 acre of plantation,

e is the annual cost per acre of maintenance,

r is the rotation,

and p is the rate of interest.

If all the other factors are known, a value of p can be calculated which makes the two sides of the equation equal. This is the rate of compound interest which the plantation has earned on the fluctuating amount of capital which is invested in it. A rate of interest of between 3 and 4 per cent. is usually expected from money spent in establishing and maintaining plantations.

The cost of establishing a plantation 60 years ago, say in 1888, was much less than it is to-day; wages were then about one-sixth, or one-seventh, of what they are now, and, as nearly all the cost of planting is represented by wages, the cost has probably risen six or seven times in the interval. Maintenance costs were also lower then and have gradually risen during the intervening period. It follows that prices which would enable such a plantation to yield just 4 per cent. on the capital actually invested would be much lower than prices which would be required to yield 4 per cent. on a plantation established at present costs.

It is open to dispute whether prices should be based on the actual costs or on the cost of replacement; and the difference between the two values is very large. It must be borne in mind that not only wages but the cost of nearly all commodities has risen during the period; i.e. the purchasing value of the pound has fallen. As the owner of the plantation is being reimbursed in a devalued currency, it is reasonable that he should receive more pounds in 1948 than he would have required in 1888; but, as prices in general have risen much less than woodmen's wages, he should not expect prices to keep pace with wages.

(b) *Prices must be high enough to make the continued cultivation of woodlands*

remunerative. This is clearly necessary as, otherwise, forest cultivation will cease except in so far as the State or private individuals are prepared to run it at a loss.

The profit from forestry is a difficult figure to assess. During a war a woodland owner may be constrained to fell much more timber than is sylviculturally desirable; he will then receive a large cash income, most of which will be capital which he is realizing. If the woods are to be re-established he will subsequently have to reinvest some of this capital and, during this period, his expenditure will exceed his income. The actual excess of income over expenditure in any one year is not, therefore, a fair test of the profit from his woods.

If, however, his woods collectively constituted a *normal forest*, i.e. a forest in which all ages are equally represented, he might carry out each year all the operations of forestry—establishment, brashing, cleaning, thinning at all ages, and maintenance—and he would receive all the appropriate returns—from thinnings and final yield. And at the end of the year the volume felled would have been replaced by the growth of the remaining trees. His capital would be the same at the end of the year as at the beginning, and any excess of income over expenditure during the year could justly be regarded as profit.

It follows that prices of timber should be sufficiently high to enable the owner of a normal forest, who manages it with reasonable efficiency on a system of sustained yield, to earn a profit. If prices are so low that his gross income is less than his expenditure, then, in time, he must give up cultivation. His economic course would then be to fell his woods as soon as they were mature and not to replant. He would gradually devastate his woods.

Calculations in forest finance are greatly simplified if it is assumed that the costs of labour and purchases and the prices of timber remain constant during a rotation, i.e. the period during which a normal forest is built up. It can then be shown that the rate of interest which the net income from a normal forest represents on the capital cost of creating the normal forest is equal to the rate of compound interest which is calculated by the Faustmann formula for a single plantation.

As, however, wages are now many times what they were 40 or 50 years ago, this relationship does not now hold good. For example, on the basis of the figures used in this paper, it may be shown that a forester who sells the timber in a 100-year old plantation of second-quality Scots pine at present prices will have earned 3 per cent. compound interest on his invested capital. Nevertheless, the running of a normal forest of Scots pine, Quality II, at the present time would show an annual loss. These are conditions which must inevitably lead to devastation.

To enable a normal forest of Scots pine, Quality II, to yield a return of $2\frac{1}{2}$ per cent. on past costs would require an increase in prices of about 90 per cent. But to enable a normal forest created at present costs to yield $2\frac{1}{2}$ per cent., prices would have to be raised to four or five times what they are to-day. In 100 years' time, when plantations initiated now become mature, prices may be at the latter level. All that should be claimed at the present time is that a normal forest should be able to earn a fair rate of interest on its past costs.

III. THE NET PROFIT FROM A NORMAL FOREST.

1. *The estimates required.*

There are no normal forests in Britain to-day. Even if foresters had attempted to manage their woods on a sustained yield basis for a long enough period to create normal forests, their efforts would have been frustrated by the excess fellings which were required during the two wars. It is consequently impossible to determine the net profit which is being earned from actual examples, and we have to fall back on estimates. *Two estimates are required:* (a) the gross income, (b) the gross expenditure.

2. *The gross income from a normal forest.*

The gross income can be determined with reasonable accuracy. The volume of timber which might be felled each year can be calculated from the *Forestry Commission Yield Tables* (3), and the maximum prices which should be put on this timber can be calculated from the maximum control prices.

Maximum control prices (1) are fixed for (a) growing trees, (b) round timber at stump, and (c) round timber at station. In the present calculations I have used the prices of round timber at stump. My reason for this is that standing thinnings are seldom saleable owing to the difficulty and extra cost of felling them; the price which should be attached to them is consequently doubtful. The price at station is also unsuitable because extraction and delivery to station are very variable costs.

The early thinnings, which are under 3 inches in diameter, are not controlled. These must, however, be cut, and I have assumed that the woodland staff fells these thinnings, carries them to ride-side, and cuts them up into stakes and other products. In general the earliest thinnings do not yield a net profit; but they can be sold, and the sale price from them has to be included in the gross income.

Calculations of the gross income from normal forests are shown in Appendix I, where tables are reproduced for three quality classes of Scots pine and four quality classes of European larch, Norway spruce, and Douglas fir.

The most difficult step in the preparation of these tables is from the volume of thinnings or final yield to their prices. The maximum control price of a pole depends on its quarter-girth at mid-timber height; but the only dimension given in the *Forestry Commission Yield Tables* (3) is quarter-girth at breast height of the main crop. Converting factors had, therefore, to be prepared showing (a) the relation of mid-timber Q.G. to breast height Q.G., and (b) the relation of breast height Q.G. of thinnings to breast height Q.G. of main crop. A correction has also to be made to allow for (c) the variation of size within the crop. Thus the maximum price of a Scots pine with Q.G., MT.H. of 7 inches is 11d., whereas the price for an 8 inch Q.G. tree is 1s. 2½d. In a plantation with an average Q.G., MT.H. of 7 inches some of the trees will be over 9 inches, whereas, if the average Q.G., MT.H. is 8 inches, some of the trees will be under 8 inches. To allow for this it is necessary to make observations on the spread of quarter-girths within a plantation.

(a) *Relation of Q.G., mid-timber height to Q.G., breast height.* The relationship used in this paper is shown in Graph A, where it is represented by a straight line. The line shown is based on a number of records derived from measurements of sample plots of Norway spruce, Sitka spruce (*Picea sitchensis* Carr.), European larch, and Douglas fir, and I have used, for comparison, figures from Davey's *Measurement of Trees* (1942) (2).

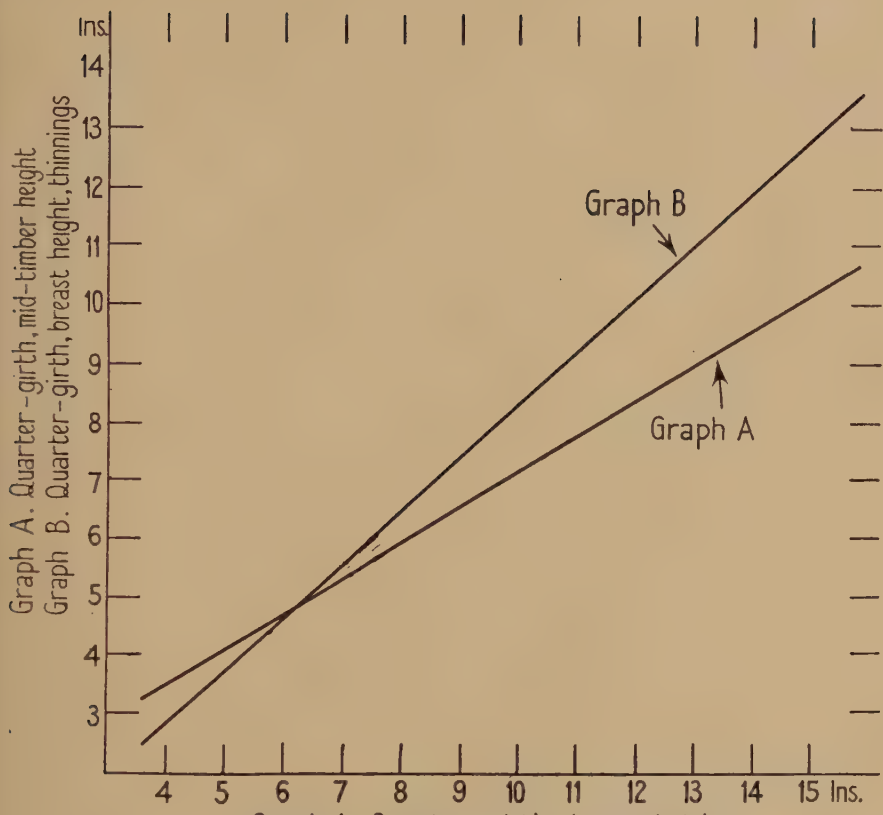
(b) *Relation of breast height Q.G. of thinnings to breast height Q.G. of main crop.* The relationship between these measurements, which also appears to be linear, is shown in Graph B. This graph was also derived from sample plot measurements; but I am indebted to the Research Branch of the Forestry Commission for preparing, and allowing me to see, graphs showing this relationship for a very large number of sample plots of various species. The position of the point on the graph which represents the result of a particular thinning naturally depends on the nature of the thinning. In a low thinning there is a very marked disparity between the size of the thinnings and the size of the main crop, whereas in a crown thinning there may be little difference between them. Also, a light low thinning gives a greater disparity than a heavy low thinning. The graph I had already constructed from my own recorded thinnings of Scots pine, European larch, Norway spruce, and Douglas fir was well within the range of the examples provided by the Forestry Commission for the same species, and it did not appear necessary to adopt different lines for different species.

(c) *The spread of quarter-girths within a single crop.* For this determination I used a dispersion graph showing the number of individuals which fell within the classes of breast height quarter-girths in a felling of a mixed wood of 174 Douglas fir and Norway spruce. The spruce was many years older than the Douglas, but the trees of the two species were about the same size. The mode of the curve for each species lay in the class 6 to $6\frac{1}{8}$ inches, and the limits for each species were $3\frac{1}{2}$ and 11 inches.

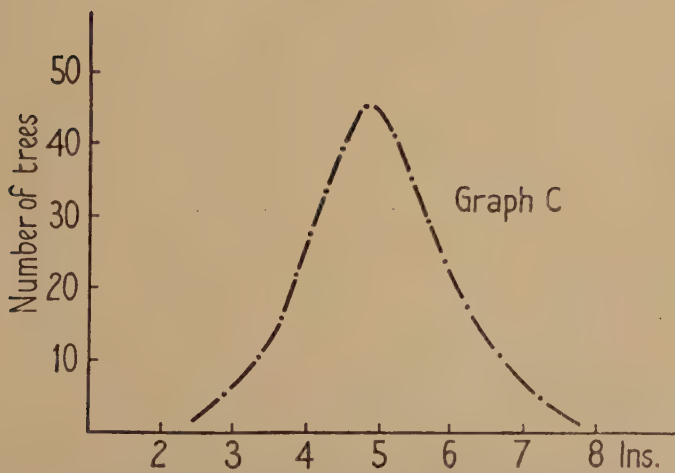
The mid-timber quarter-girths of these trees were estimated by means of Graph A. These quarter-girths averaged 5.2 inches, and, for convenience, all the readings were reduced by 0.2 inch so that the average became 5 inches. Their distribution was then graphed as shown in Graph C, and the number of squares included by the curve above the base for $2-2\frac{1}{2}$, $2\frac{1}{2}-3$, $3-3\frac{1}{2}$, ... $7\frac{1}{2}-8$ inches was counted. From these figures the percentage of the total volume in the wood which was included in each quarter-girth class was calculated, and these percentages were also graphed. The results showed that:

1% of the volume was contained in trees less than 3 in. Q.G., MT.H.						
7%	"	"	"	"	"	4 in.
36%	"	"	"	"	"	5 in.
64%	"	"	"	more	"	5 in.
27%	"	"	"	"	"	6 in.
6%	"	"	"	"	"	7 in.

It was assumed that if the mean Q.G., MT.H. was larger or smaller than 5 inches, then the spread of quarter-girths about this mean would be proportional



Graph A. Quarter-girth, breast height.
Graph B. Quarter-girth, breast height, main crop.



Graph C. Quarter-girth, mid-timber height

to the quarter-girth of the mean tree. Using this relationship the values per 100 cu. ft. in Table I were worked out for woods of larch and of conifers other than larch with various mean quarter-girths at mid-timber height.

The results of the steps described above under the headings (a), (b), and (c) are expressed in Table II, which shows the relationship of mean Q.G., B.H. of main crop to mean Q.G., B.H. of thinnings, mean Q.G., M.T.H. of main crop and thinnings, and the maximum price of round timber at stump of main crop and thinnings.

It is necessary to point out the limitations of this table. It was prepared for the purpose of this paper and should not be used, except as a very rough guide, for valuing the main crop or thinnings of any one plantation. Individual plantations differ very widely from each other owing to the degree and nature of the thinnings and the taper and evenness in size of the trees. It is probable that, if more careful statistics were collected, individual tables could be prepared which would be more closely applicable to particular species. It is considered, however, that the table is sufficiently accurate for use in the present discussion.

The income from a normal forest can now be estimated. It is assumed:

- (i) That the thinnings in plantations in which the main crop has a Q.G., B.H. of less than 5 inches are cut by the woodland staff, carried to ride, and cut up into stakes and other products and sold as such.
- (ii) That all other thinnings are felled and trimmed and sold at stump.
- (iii) That the average yield of main crop and thinnings is 80 per cent. of the volumes set out in the *Yield Tables*. This is a reasonable efficiency to expect.
- (iv) That an average of 90 per cent. of the maximum price is obtained for all these thinnings. The allowance of 10 per cent. is for crooked stems, the give-and-take in measurement, and general wastage. At present it would not be possible to sell small thinnings at as high a price as this except under very favourable conditions; the controlled price of pitprops is too low to allow a purchaser to pay so much. For this reason the calculated incomes from normal forests which are shown in columns 4 and 5 of Table III are higher than could generally be obtained at present. If the prices of pitprops were raised, even without any concomitant rise in the prices of round timber, the incomes shown in the table might be realizable.
- (v) That Scots pine is worked on a rotation of 100 years; European larch, 80 years; Norway spruce, 70 years; and Douglas fir, 50 years. These are the longest rotations which are covered by the *Yield Tables*, but it cannot be assumed from this that they are the most favourable rotations from a financial point of view. Calculations have shown that with present prices and costs they do actually represent an approximation to the financial rotations, and they have consequently been adopted. This matter is further discussed in Appendix IV.

In Appendix I the method of calculating the gross income from normal forests of Scots pine, European larch, Norway spruce, and Douglas fir is displayed. In

the tables in this appendix the early thinnings are credited with a price per lineal foot which might be secured when they have been converted to stakes, &c., and are sold at ride-side. The remaining thinnings have been priced according to Table II, in which the prices are the maximum prices for round timber felled at stump.

The manner in which the figures are used can be explained by reference to the first table, that for Scots pine, Quality I. The total volume (omitting very small thinnings), according to the *Yield Tables*, which can be cut each year in a normal forest of 100 acres is 8,425 cu. ft. Allowing for an average efficiency of 80 per cent., this is reduced to 6,740 cu. ft. The total value which would be received from the full volume sold at maximum prices is £505. This is reduced by 28 per cent. (20 per cent. for volume and 10 per cent. for price) to become £364.

TABLE I. *The relation of maximum price at stump to mean quarter-girth at mid-timber height.*

(a) *Conifers other than larch*

Q.G. MT.H. in.	Percent. of volume in price categories			Price per 100 cu. ft. £		Price per cu. ft. d.
	11d.	14½d.	17d.			
5	100	..	..	4.58	= 4.58	11.0
6	99	1	..	4.54+0.06	= 4.60	11.0
7	68	32	..	3.12+1.93	= 5.05	12.1
8	36	64	..	1.65+3.87	= 5.52	13.2
9	12	88	..	0.55+5.32	= 5.87	14.1
10	3	79	18	0.14+4.77+1.27	= 6.18	14.8
11	1	61	38	0.05+3.68+2.69	= 6.42	15.4
12	..	36	64	2.18+4.53	= 6.71	16.1
13	..	16	84	0.97+5.95	= 6.92	16.6
14	..	6	94	0.36+6.66	= 7.02	16.8
15	..	2	98	0.12+6.94	= 7.06	16.9
16	..	..	100	7.08	= 7.08	17.0

(b) *Larch (Larix decidua Mill.)*

Q.G. MT.H. in.	Percent. of volume in price categories			Price per 100 cu. ft. £		Price per cu. ft. d.
	11d.	17d.	24½d.			
4	96	4	..	4.40+0.28	= 4.68	11.2
5	74	26	..	3.39+1.84	= 5.23	12.6
6	36	64	..	1.65+4.53	= 6.18	14.8
7	10	90	..	0.46+6.57	= 6.83	16.4
8	2	85	13	0.09+6.02+1.33	= 7.44	17.9
9	..	64	36	4.53+3.67	= 8.20	19.7
10	..	36	64	2.55+6.53	= 9.08	21.8
11	..	14	86	0.99+8.78	= 9.77	23.4
12	..	5	95	0.35+9.70	= 10.05	24.1

TABLE II. Relationship of size and maximum price, felled at stump, of main crop and thinnings

Mean Q.G., B.H. Main crop (1)	Main Crop				Thinnings						
	Q.G. MT.H. (2)	Larch		Other Conifers		Q.G. B.H. (7)	Q.G. MT.H. (8)	Larch		Other Conifers	
		Price per 100 cu.ft. (3)	Price per cu.ft. (4)	Price per 100 cu.ft. (5)	Price per cu.ft. (6)			Price per 100 cu.ft. (9)	Price per cu.ft. (10)	Price per 100 cu.ft. (11)	Price per cu.ft. (12)
in.	in.	£	d.	£	d.	in.	in.	£	d.	£	d.
4	3'5	4'58	11'0	4'58	11'0	2'8	..	..	..	..	..
1 1/2	3'6	"	"	"	"	3'0	..	..	..	..	..
2 1/2	3'8	"	"	"	"	3'2	..	..	..	..	..
3 1/2	3'9	4'60	"	"	"	3'5	..	..	..	..	..
5	4'1	4'69	11'3	"	"	3'7	..	..	..	..	..
1 1/2	4'2	4'78	11'5	"	"	4'0	3'5	4'58	11'0	4'58	11'0
2 1/2	4'4	4'87	11'7	"	"	4'2	3'6	"	"	"	"
3 1/2	4'5	4'97	11'9	"	"	4'5	3'8	"	"	"	"
6	4'7	5'08	12'2	"	"	4'7	3'9	4'60	11'0	"	"
1 1/2	4'8	5'20	12'5	"	"	4'9	4'0	4'69	11'3	"	"
2 1/2	5'0	5'32	12'8	"	"	5'1	4'1	4'78	11'5	"	"
3 1/2	5'2	5'44	13'1	"	"	5'4	4'3	4'87	11'7	"	"
7	5'3	5'57	13'4	"	"	5'6	4'5	4'95	11'9	"	"
1 1/2	5'5	5'71	13'7	"	"	5'8	4'6	5'04	12'1	"	"
2 1/2	5'6	5'84	14'0	"	"	6'1	4'7	5'14	12'3	"	"
3 1/2	5'8	5'97	14'3	"	"	6'3	4'9	5'25	12'6	"	"
8	5'9	6'09	14'6	"	"	6'5	5'0	5'35	12'8	"	"
1 1/2	6'1	6'21	14'9	"	"	6'8	5'2	5'46	13'1	"	"
2 1/2	6'3	6'33	15'2	"	"	7'0	5'3	5'58	13'4	"	"
3 1/2	6'4	6'44	15'5	"	"	6'3	5'5	5'70	13'7	"	"
9	6'5	6'55	15'7	"	"	7'5	5'6	5'82	14'0	"	"
1 1/2	6'7	6'66	16'0	"	"	7'7	5'8	5'94	14'3	"	"
2 1/2	6'9	6'77	16'2	"	"	8'0	5'9	6'06	14'5	"	"
3 1/2	7'1	6'87	16'5	"	"	8'2	6'1	6'18	14'8	4'62	11'1

10	10.1 10.2 10.3 10.4 10.5 10.6 10.7 10.8 10.9 11.0 11.1 11.2 11.3 11.4 11.5 11.6 11.7 11.8 11.9 12.0 12.1 12.2 12.3 12.4 12.5 12.6 12.7 12.8 12.9 13.0 13.1 13.2 13.3 13.4 13.5 13.6 13.7 13.8 13.9 14.0 14.1 14.2 14.3 14.4 14.5	7.2 7.3 7.5 7.7 7.8 7.9 8.1 8.2 8.4 8.5 8.7 8.8 9.0 9.2 9.3 9.5 9.6 9.8 9.9 10.1 10.2 10.4 10.6 10.8 10.9	6.97 7.06 7.15 7.24 7.33 7.41 7.50 7.60 7.71 7.82 7.94 8.07 8.21 8.35 8.49 8.63 8.76 8.89 9.01 9.13 9.25 9.36 9.47 9.59 9.70	16.7 16.9 17.2 17.4 17.6 17.8 18.0 18.2 18.5 18.8 19.1 19.4 19.7 20.0 20.4 20.7 21.0 21.3 21.6 21.9 22.2 22.5 22.7 23.0 23.3	5.15 5.22 5.29 5.36 5.42 5.48 5.53 5.59 5.65 5.71 5.76 5.82 5.87 5.92 5.97 6.02 6.07 6.11 6.16 6.20 6.24 6.28 6.32 6.36 6.40	12.4 12.5 12.7 12.9 13.0 13.2 13.3 13.4 13.6 13.7 13.8 14.0 14.1 14.2 14.3 14.4 14.6 14.7 14.8 14.9 15.0 15.1 15.2 15.3 15.4	8.4 8.6 8.9 9.1 9.3 9.6 9.8 10.1 10.3 10.5 10.8 11.0 11.2 11.4 11.7 11.9 12.1 12.3 12.6 12.8 13.0 13.2 13.4 13.7 13.9	6.2 6.3 6.5 6.7 6.8 6.9 7.1 7.2 7.3 7.5 7.6 7.8 7.9 8.0 8.2 8.3 8.4 8.5 8.7 8.8 9.0 9.1 9.3 9.4 9.6	6.29 6.40 6.50 6.60 6.69 6.77 6.86 6.94 7.03 7.13 7.22 7.31 7.40 7.49 7.57 7.66 7.76 7.86 7.97 8.08 8.20 8.32 8.45 8.59 8.73	15.1 15.4 15.6 15.8 16.1 16.2 16.5 16.7 16.9 17.1 17.3 17.5 17.8 18.0 18.2 18.4 18.6 18.9 19.1 19.4 19.7 20.0 20.3 20.6 21.0	4.67 4.73 4.80 4.87 4.93 5.00 5.07 5.13 5.20 5.26 5.33 5.39 5.45 5.51 5.57 5.62 5.67 5.72 5.77 5.82 5.87 5.92 5.97 6.01 6.05	11.2 11.4 11.5 11.7 11.8 12.0 12.2 12.3 12.5 12.6 12.8 12.9 13.1 13.2 13.4 13.5 13.6 13.7 13.8 14.0 14.1 14.2 14.3 14.4 14.5
11	11.1 11.2 11.3 11.4 11.5 11.6 11.7 11.8 11.9 12.0 12.1 12.2 12.3 12.4 12.5 12.6 12.7 12.8 12.9 13.0 13.1 13.2 13.3 13.4 13.5 13.6 13.7 13.8 13.9 14.0 14.1 14.2 14.3 14.4 14.5 14.6 14.7 14.8 14.9 15.0 15.1 15.2 15.3 15.4 15.5 15.6 15.7 15.8 15.9 16.0 16.1 16.2 16.3 16.4 16.5 16.6 16.7 16.8 16.9 17.0 17.1 17.2 17.3 17.4 17.5 17.6 17.7 17.8 17.9 18.0 18.1 18.2 18.3 18.4 18.5 18.6 18.7 18.8 18.9 19.0 19.1 19.2 19.3 19.4 19.5 19.6 19.7 19.8 19.9 20.0 20.1 20.2 20.3 20.4 20.5 20.6 20.7 20.8 20.9 21.0 21.1 21.2 21.3 21.4 21.5 21.6 21.7 21.8 21.9 22.0 22.1 22.2 22.3 22.4 22.5 22.6 22.7 22.8 22.9 23.0 23.1 23.2 23.3 23.4 23.5 23.6 23.7 23.8 23.9 24.0 24.1 24.2 24.3 24.4 24.5 24.6 24.7 24.8 24.9 25.0 25.1 25.2 25.3 25.4 25.5 25.6 25.7 25.8 25.9 26.0 26.1 26.2 26.3 26.4 26.5 26.6 26.7 26.8 26.9 27.0 27.1 27.2 27.3 27.4 27.5 27.6 27.7 27.8 27.9 28.0 28.1 28.2 28.3 28.4 28.5 28.6 28.7 28.8 28.9 29.0 29.1 29.2 29.3 29.4 29.5 29.6 29.7 29.8 29.9 30.0 30.1 30.2 30.3 30.4 30.5 30.6 30.7 30.8 30.9 31.0 31.1 31.2 31.3 31.4 31.5 31.6 31.7 31.8 31.9 32.0 32.1 32.2 32.3 32.4 32.5 32.6 32.7 32.8 32.9 33.0 33.1 33.2 33.3 33.4 33.5 33.6 33.7 33.8 33.9 34.0 34.1 34.2 34.3 34.4 34.5 34.6 34.7 34.8 34.9 35.0 35.1 35.2 35.3 35.4 35.5 35.6 35.7 35.8 35.9 36.0 36.1 36.2 36.3 36.4 36.5 36.6 36.7 36.8 36.9 37.0 37.1 37.2 37.3 37.4 37.5 37.6 37.7 37.8 37.9 38.0 38.1 38.2 38.3 38.4 38.5 38.6 38.7 38.8 38.9 39.0 39.1 39.2 39.3 39.4 39.5 39.6 39.7 39.8 39.9 40.0 40.1 40.2 40.3 40.4 40.5 40.6 40.7 40.8 40.9 41.0 41.1 41.2 41.3 41.4 41.5 41.6 41.7 41.8 41.9 42.0 42.1 42.2 42.3 42.4 42.5 42.6 42.7 42.8 42.9 43.0 43.1 43.2 43.3 43.4 43.5 43.6 43.7 43.8 43.9 44.0 44.1 44.2 44.3 44.4 44.5 44.6 44.7 44.8 44.9 45.0 45.1 45.2 45.3 45.4 45.5 45.6 45.7 45.8 45.9 46.0 46.1 46.2 46.3 46.4 46.5 46.6 46.7 46.8 46.9 47.0 47.1 47.2 47.3 47.4 47.5 47.6 47.7 47.8 47.9 48.0 48.1 48.2 48.3 48.4 48.5 48.6 48.7 48.8 48.9 49.0 49.1 49.2 49.3 49.4 49.5 49.6 49.7 49.8 49.9 50.0 50.1 50.2 50.3 50.4 50.5 50.6 50.7 50.8 50.9 51.0 51.1 51.2 51.3 51.4 51.5 51.6 51.7 51.8 51.9 52.0 52.1 52.2 52.3 52.4 52.5 52.6 52.7 52.8 52.9 53.0 53.1 53.2 53.3 53.4 53.5 53.6 53.7 53.8 53.9 54.0 54.1 54.2 54.3 54.4 54.5 54.6 54.7 54.8 54.9 55.0 55.1 55.2 55.3 55.4 55.5 55.6 55.7 55.8 55.9 56.0 56.1 56.2 56.3 56.4 56.5 56.6 56.7 56.8 56.9 57.0 57.1 57.2 57.3 57.4 57.5 57.6 57.7 57.8 57.9 58.0 58.1 58.2 58.3 58.4 58.5 58.6 58.7 58.8 58.9 59.0 59.1 59.2 59.3 59.4 59.5 59.6 59.7 59.8 59.9 60.0 60.1 60.2 60.3 60.4 60.5 60.6 60.7 60.8 60.9 61.0 61.1 61.2 61.3 61.4 61.5 61.6 61.7 61.8 61.9 62.0 62.1 62.2 62.3 62.4 62.5 62.6 62.7 62.8 62.9 63.0 63.1 63.2 63.3 63.4 63.5 63.6 63.7 63.8 63.9 64.0 64.1 64.2 64.3 64.4 64.5 64.6 64.7 64.8 64.9 65.0 65.1 65.2 65.3 65.4 65.5 65.6 65.7 65.8 65.9 66.0 66.1 66.2 66.3 66.4 66.5 66.6 66.7 66.8 66.9 67.0 67.1 67.2 67.3 67.4 67.5 67.6 67.7 67.8 67.9 68.0 68.1 68.2 68.3 68.4 68.5 68.6 68.7 68.8 68.9 69.0 69.1 69.2 69.3 69.4 69.5 69.6 69.7 69.8 69.9 70.0 70.1 70.2 70.3 70.4 70.5 70.6 70.7 70.8 70.9 71.0 71.1 71.2 71.3 71.4 71.5 71.6 71.7 71.8 71.9 72.0 72.1 72.2 72.3 72.4 72.5 72.6 72.7 72.8 72.9 73.0 73.1 73.2 73.3 73.4 73.5 73.6 73.7 73.8 73.9 74.0 74.1 74.2 74.3 74.4 74.5 74.6 74.7 74.8 74.9 75.0 75.1 75.2 75.3 75.4 75.5 75.6 75.7 75.8 75.9 76.0 76.1 76.2 76.3 76.4 76.5 76.6 76.7 76.8 76.9 77.0 77.1 77.2 77.3 77.4 77.5 77.6 77.7 77.8 77.9 78.0 78.1 78.2 78.3 78.4 78.5 78.6 78.7 78.8 78.9 79.0 79.1 79.2 79.3 79.4 79.5 79.6 79.7 79.8 79.9 80.0 80.1 80.2 80.3 80.4 80.5 80.6 80.7 80.8 80.9 81.0 81.1 81.2 81.3 81.4 81.5 81.6 81.7 81.8 81.9 82.0 82.1 82.2 82.3 82.4 82.5 82.6 82.7 82.8 82.9 83.0 83.1 83.2 83.3 83.4 83.5 83.6 83.7 83.8 83.9 84.0 84.1 84.2 84.3 84.4 84.5 84.6 84.7 84.8 84.9 85.0 85.1 85.2 85.3 85.4 85.5 85.6 85.7 85.8 85.9 86.0 86.1 86.2 86.3 86.4 86.5 86.6 86.7 86.8 86.9 87.0 87.1 87.2 87.3 87.4 87.5 87.6 87.7 87.8 87.9 88.0 88.1 88.2 88.3 88.4 88.5 88.6 88.7 88.8 88.9 89.0 89.1 89.2 89.3 89.4 89.5 89.6 89.7 89.8 89.9 90.0 90.1 90.2 90.3 90.4 90.5 90.6 90.7 90.8 90.9 91.0 91.1 91.2 91.3 91.4 91.5 91.6 91.7 91.8 91.9 92.0 92.1 92.2 92.3 92.4 92.5 92.6 92.7 92.8 92.9 93.0 93.1 93.2 93.3 93.4 93.5 93.6 93.7 93.8 93.9 94.0 94.1 94.2 94.3 94.4 94.5 94.6 94.7 94.8 94.9 95.0 95.1 95.2 95.3 95.4 95.5 95.6 95.7 95.8 95.9 96.0 96.1 96.2 96.3 96.4 96.5 96.6 96.7 96.8 96.9 97.0 97.1 97.2 97.3 97.4 97.5 97.6 97.7 97.8 97.9 98.0 98.1 98.2 98.3 98.4 98.5 98.6 98.7 98.8 98.9 99.0 99.1 99.2 99.3 99.4 99.5 99.6 99.7 99.8 99.9 100.0 100.1 100.2 100.3 100.4 100.5 100.6 100.7 100.8 100.9 101.0 101.1 101.2 101.3 101.4 101.5 101.6 101.7 101.8 101.9 102.0 102.1 102.2 102.3 102.4 102.5 102.6 102.7 102.8 102.9 103.0 103.1 103.2 103.3 103.4 103.5 103.6 103.7 103.8 103.9 104.0 104.1 104.2 104.3 104.4 104.5 104.6 104.7 104.8 104.9 105.0 105.1 105.2 105.3 105.4 105.5 105.6 105.7 105.8 105.9 106.0 106.1 106.2 106.3 106.4 106.5 106.6 106.7 106.8 106.9 107.0 107.1 107.2 107.3 107.4 107.5 107.6 107.7 107.8 107.9 108.0 108.1 108.2 108.3 108.4 108.5 108.6 108.7 108.8 108.9 109.0 109.1 109.2 109.3 109.4 109.5 109.6 109.7 109.8 109.9 110.0 110.1 110.2 110.3 110.4 110.5 110.6 110.7 110.8 110.9 111.0 111.1 111.2 111.3 111.4 111.5 111.6 111.7 111.8 111.9 112.0 112.1 112.2 112.3 112.4 112.5 112.6 112.7 112.8 112.9 113.0 113.1 113.2 113.3 113.4 113.5 113.6 113.7 113.8 113.9 114.0 114.1 114.2 114.3 114.4 114.5 114.6 114.7 114.8 114.9 115.0 115.1 115.2 115.3 115.4 115.5 115.6 115.7 115.8 115.9 116.0 116.1 116.2 116.3 116.4 116.5 116.6 116.7 116.8 116.9 117.0 117.1 117.2 117.3 117.4 117.5 117.6 117.7 117.8 117.9 118.0 118.1 118.2 118.3 118.4 118.5 118.6 118.7 118.8 118.9 119.0 119.1 119.2 119.3 119.4 119.5 119.6 119.7 119.8 119.9 120.0 120.1 120.2 120.3 120.4 120.5 120.6 120.7 120.8 120.9 121.0 121.1 121.2 121.3 121.4 121.5 121.6 121.7 121.8 121.9 122.0 122.1 122.2 122.3 122.4 122.5 122.6 122.7 122.8 122.9 123.0 123.1 123.2 123.3 123.4 123.5 123.6 123.7 123.8 123.9 124.0 124.1 124.2 124.3 124.4 124.5 124.6 124.7 124.8 124.9 125.0 125.1 125.2 125.3 125.4 125.5 125.6 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The method of calculation shows the gross income from a forest of r acres, where r is the rotation; and this figure is shown in column 4 of Table III. The gross income for 100 acres, which is shown in column 5, is calculated by multiplying the figure in column 4 by $100/r$.

3. *The gross expenditure on a normal forest.*

It is not possible to estimate the gross expenditure with as much confidence as the gross income. But a reasonably reliable figure can be deduced from the number of men whom it would be necessary to employ per 100 acres of forest. As no normal forests of coniferous species at present exist in Britain, there are no reliable data of the amount of labour which would be required to maintain them. We have, therefore, to rely to some extent on guesses. But certain figures are available as a basis for these guesses, and many practical foresters are coming to have fairly definite opinions as to how many men they will need.

It is clear that plantations of a fast-growing species, such as Douglas fir, will require more labour per 100 acres than plantations of a slow-growing species such as Scots pine. As Douglas fir may be worked on a rotation of 50 years as compared with 100 years for Scots pine, the former will have to be planted twice as often as the latter on the same ground; and the operations of weeding, cleaning, and brashing will be done twice in a century instead of once on the same land. Also Douglas fir in 50 years produces far more timber than Scots pine in 100 years. Thus we should expect a normal forest of 100 acres of Douglas fir to occupy more than twice as much labour as 100 acres of Scots pine. For similar reasons plantations on first quality land will employ more labour than plantations on lower-quality land. Nevertheless, there are some forest occupations which do not greatly vary with the species or site quality; these are principally the making and maintenance of roads, fences and drains, and protection against fire, rabbits, and other hazards.

It seems reasonable, therefore, to assess the number of men required per 100 acres as the sum of two figures: (a) a fixed number which is required regardless of species and site quality, and (b) a number which varies with the rate of growth of the trees.

I have here adopted the following formula, the chief justification of which is that it gives results which appear reasonable.

$$\begin{array}{ccc} (a) & & (b) \\ \text{No. of men required} & & \\ \text{per 100 acres} = 0.5 + & \frac{\text{volume of timber cut each year on 100 acres}}{30 \times 275} \end{array}$$

The figure of 0.5 man per 100 acres—or 1 man per 200 acres—represents the work required regardless of species and site quality. Where woods are large and roads are easy to maintain, the figure might be less than this; but with the small, scattered woodlands which compose the forest area on most private estates, the maintenance of fences, roads, and drains, together with the protection against fire, rabbits, and other pests, will occupy more than one man per 200 acres. The following quotation from *Post-War Forest Policy* (7), para. 207, suggests that it is

an appropriate figure for State forests during a period when work on actual cultivation is very light: 'It is difficult to state a good average employment figure for the maintenance of plantations between planting and the brashing stage. A rough approximation is one man per 200 acres.'

The second part of the formula was suggested by a statement in Heske's *German Forestry* (4), p. 163, to the effect that in 1927 employment in the Prussian State forests amounted to 1 man-day for every 35 cu. ft. (equals 27.5 cu. ft. quarter-girth) of stem-wood cut. It is not clear how many kinds of work this labour strength covers, but a paragraph on the following page indicates that it does not include 'teamsters and other persons engaged in hauling timber' or 'operations such as peeling mine timbers and pulpwood'. It might, therefore, correspond fairly closely with the assumption in this paper that the forest labour cuts all the trees but does not extract or work up timber other than small thinnings.

Employment per 100 acres in Britain is likely to be more than in Prussia in 1927 because our labour is less skilled and works shorter hours, and we cannot rely to the same extent on natural regeneration. Further, the figure of 1 man-day per 27.5 cu. ft., Q.G. is based on the experience of the Prussian State forests. Britain as a whole, with its large area in small woodlands on private estates, will require much more labour than this, and it is reasonable to suppose that the total employment in maintenance, cultivation, and felling in British woods would amount to about 1 man-day per 20 cu. ft., Q.G. We have already allowed 1 man's whole time for every 200 acres for maintenance; if, in addition to this, we allow 1 man-day for each 30 cu. ft. cut, the total employment works out at about this figure. To be more exact: if we imagine fifteen normal forests, each of 100 acres, of which one is composed of each of the species and quality classes listed in Table III, then the total volume cut each year will be 148,821 cu. ft.; and if each normal forest employs the amount of labour indicated in column 6 of Table III, the total employment will be 25.54 man-years or 7,024 man-days. This is equivalent to 21.2 cu. ft. per man-day.

Calculated in this manner, it appears that the lowest rate of employment is with European larch, Quality V, where it amounts to 0.94 man per 100 acres, or 1 man per 106 acres. The highest rate is with Douglas fir, Quality I, where it is 2.81 men per 100 acres or 1 man per 36 acres. The average is 1.63 men per 100 acres or 1 man per 61 acres. These figures of employment are lower than most foresters will admit as the necessary minimum for efficient forest management. In *Post-War Forest Policy* (7), para. 204, it is stated that in Rendlesham Forest (which is chiefly pine) 200 men will be required on 6,500 acres (3.08 men per 100 acres) when the oldest plantations are 31 years old; and in private conversation several State foresters have told me that they will require 4 men per 100 acres when their forests are normal. These foresters, however, may have been influenced by the heavy demand for labour which plantations in the early thinning stages always create, and they may find that they can do with less labour when an appropriate proportion of their woods has passed this stage.

Also, most foresters hope to earn a larger gross income by preparing with

their own labour transmission poles, pitprops, and other products, which can be sold at higher prices than those shown in the tables in Appendix I. If such work is undertaken a larger staff will be required. It appears, therefore, that the estimates of labour shown in Table III, column 6, are justified and that, if they err, they err by being too low.

In these calculations a man-year has been taken as equivalent to 275 man-days or 50 weeks of $5\frac{1}{2}$ days each. This allows for public holidays and 1 further week's holiday with pay. Owing to absenteeism, through sickness and other causes, the average working year is less than 275 days but, as the employer does not ordinarily pay for such additional leave, it is simpler to disregard it. It should be observed, however, that in assessing the number of men who are actually engaged in forestry, the figures in column 6 of Table III may need correction.

The cost of labour and other charges. The present minimum wage for men over 21 years is 90s. per week. The employer's contributions to National Health and Unemployment Insurances and the cost of Employer's Liability Insurance amount to about 4s. $1\frac{1}{2}d.$ per week. The least cost of employing a man at minimum wage is thus about £245 per annum. As many of the men receive more than the minimum wage and are allowed cottages at uneconomic rents, the actual cost to the employer is considerably more than this; I have, therefore, assumed that the total cost is £250 per annum.

In addition to wages for labour there will be costs of supervision, office work, transport of staff, cycle allowances, and cars for transport, and purchases. It is impossible to specify these charges in detail, and the cost of supervision and office work will vary very much according to the conditions under which the estate or forest is administered. By assuming that timber (other than small trees which the men can carry to ride) is sold at stump, the cost of horses, tractors, and lorries for extraction and haulage has been eliminated, but 'purchases' will still include seed, wire netting, tools, road metal, car hire, and cycle allowances for conveying men to their work, fire insurance on the woods, stationery, and office maintenance. It is unlikely that the cost of supervision and maintenance can amount to less than 30 per cent. on wages; and, although I have adopted this figure so as not unduly to swell the calculated costs, my experience tends to show that it is definitely on the low side.

The annual cost per man engaged is, therefore, assessed at £250 plus 30 per cent. for supervision and purchases, or £325 per annum. Column 7 in Table III shows the product of the number of men employed per 100 acres and the annual cost per man at £325.

4. *Forestry Commission Grants.*

At the present time an owner of private woodlands is entitled to Forestry Commission Grants. These amount to £10 per acre for newly planted or naturally regenerated areas and a maintenance grant of 3s. 4d. per acre per annum on all productive woodlands. On 100 acres of a normal forest of Scots pine, grown on a rotation of 100 years, 1 acre would be planted each year, and the grants would amount to £10 plus $100 \times 3s. 4d.$, or £27. On 100 acres of Douglas fir, grown on

a rotation of 50 years, 2 acres would be planted annually and the grants would amount to £20 plus $100 \times 3s. 4d.$, or £37. Similarly for European larch, on a rotation of 80 years, they would be £29, and for Norway spruce, on a rotation of 70 years, £31. These figures are shown in column 9 of Table III.

5. *The net income from a normal forest (Table III).*

The results derived from these calculations are shown in Table III, which the following notes will explain.

Column 2 shows the rotation. This is not necessarily the financial rotation (see Appendix IV), but it gives a reasonable picture of the kind of rotations that will be required to yield saw timber of the sizes demanded by timber merchants. On very poor soil the rotations would have to be considerably longer than those shown in the *Yield Tables*, but no figures are available from which to make calculations with longer rotations, and, in any case, they are likely to be uneconomic.

Column 3 shows the volume produced annually on r acres. This is the total figure derived from the *Yield Tables*, less 20 per cent.

Column 4 shows the annual gross income which may be derived from the sales of thinnings and final yield on a normal forest of r acres, where r is the rotation.

Column 5 shows the annual gross income which may be derived from a normal forest of 100 acres. The figure is derived by multiplying the corresponding figure in column 4 by $100/r$.

Column 6 shows the number of men required per 100 acres. This figure is derived from the formula

$$\text{No. of men} = 0.5 + \frac{\text{volume of timber cut each year on 100 acres}}{30 \times 275}.$$

Column 7 shows the cost per annum of labour, purchases, and overheads, and is equal to £325 multiplied by the number of men employed.

Column 8 shows the excess of income over expenditure, i.e. column 5 minus column 7.

Column 9 shows the amount which might be received annually from Forestry Commission Grants.

Column 10 shows the profit or loss after crediting Forestry Commission Grants.

Some of the resulting figures in column 10 are negative and others are positive; and we must examine more closely what these results mean. If the figure in column 10 were 0, it would mean that the owner of the normal forest could expect to make no profit but could just cover his costs of maintaining it on a basis of sustained yield. He, or his predecessors, would have spent a large amount of money in creating this normal forest, and he might reasonably expect to earn an income which would represent interest on this capital. But on the premisses employed in this paper he would receive no interest at all and no rent on his land.

If the figure in column 10 is negative it implies that not only does the owner receive no interest on his investment nor rent on the land, but he actually has to pay out an annual sum to maintain the forest.

If the figure in column 10 is positive it implies that the owner can obtain a

TABLE III. *The balance of income and expenditure on 100 acres of normal forest of coniferous species*

Species and Quality class (1)	Rotation = τ (2)	Vol. produced annually on τ acres (3)	Ann. Gross Inc. on τ acres (4)	Ann. Gross Inc. on 100 acres (5)	No. of men employed per 100 acres (6)	Ann. expend. = No. of men multiplied by 325 (7)	Profit or loss per 100 acres. Col. 5 minus col. 7 (8)	For. Com. Grants on 100 acres (9)	Profit or loss after adding For. Com. Grants (10)
	yrs.	cu. ft.	£	£		£	£	£	£
Scots pine (<i>Pinus sylvestris</i> L.)									
SP. I	100	6,740	364	364	1.32	429	-65	27	-38
SP. II	100	5,740	315	315	1.20	390	-75	27	-48
SP. III	100	4,620	251	251	1.06	344	-93	27	-66
European larch (<i>Larix decidua</i> Mill.)									
EL. I	80	7,328	518	648	1.61	523	+125	29	+154
EL. II	80	6,180	429	536	1.43	465	+71	29	+100
EL. III	80	4,924	341	426	1.25	406	+20	29	+49
EL. V	80	2,896	202	252	0.94	305	-53	29	-24
Norway spruce (<i>Picea abies</i> Karst.)									
NS. I	70	10,224	556	794	2.27	738	+56	31	+87
NS. II	70	8,460	450	643	1.97	640	+3	31	+34
NS. III	70	6,888	355	507	1.69	549	-42	31	-11
NS. V	70	4,156	207	296	1.22	396	-100	31	-69
Douglas fir (<i>Pseudotsuga taxifolia</i> Brit.)									
DF. I	50	9,512	513	1,026	2.81	913	+113	37	+150
DF. II	50	8,352	454	908	2.52	819	+89	37	+126
DF. III	50	7,188	389	778	2.24	728	+50	37	+87
DF. IV	50	6,244	343	686	2.01	653	+33	37	+70

net income from running his normal forest; in the case of Douglas fir, Quality I, the income works out at £150 per annum on 100 acres, or £1.50 per acre. This appears to be a favourable result; but, until we know the capital cost of the forest, we cannot tell what rate of interest it represents on the investment. Estimates of the capital costs of such normal forests are given in the following section.

Assuming that the premisses on which this paper is based are correct, the results show, as we should expect, that the cultivation of trees is more profitable on good land than on bad land; but Scots pine shows an actual loss on all soil qualities, and European larch and Norway spruce on the worst qualities. All qualities of Douglas fir and the better qualities of European larch and Norway spruce show a profit.

IV. THE COST VALUE OF A NORMAL FOREST.

1. *The method employed.*

The cost value of a normal forest is made up of three factors:

- (1) The cost of the land and money spent on all the operations involved.
- (2) The money received from intermediate yields.
- (3) Compound interest on these amounts which is charged from the year in which they occurred.

The net cost is a summation of the items in (1) less a summation of the items in (2), each brought forward to the present time at some rate of compound interest.

Formulae for calculating the cost value of a normal growing stock or, by adding the value of the land, the value of a normal forest, can be found in the text-books, e.g. Schlich, *Manual of Forestry*, vol. iii (5th ed., 1945) (9), p. 148. But in these formulae it is assumed that the cost of operations and the prices of timber have remained constant over the period of formation. Up to 35 years ago this may have been a reasonable assumption to work on; but since the beginning of the First World War wages have risen to such an extent that the changes in cost can no longer be neglected.

We have no reliable records of what were the average costs of planting and thinning 50 or 100 years ago. But we have a record of wage changes. And, as wages represent nearly the whole cost of growing and felling trees, it is legitimate to suppose that the costs of these operations varied with wage rates. If, therefore, we can determine average costs of forest operations to-day, we can project these costs backwards with reasonable confidence.

2. *The classification of costs: heads under which costs are included in formulae.*

The costs of forest operations are very variable. They are influenced as much by the manual skill of the workers and the competence of management as they are by weather and the nature of the terrain. We have, therefore, to estimate average costs which are representative of woodlands managed with reasonable competence. Use can be made of actual costings, so long as these are costings conducted over a long enough period to be representative of a variety of

conditions and are so arranged as to include all the items of cost which are applicable to each operation.

In accordance with custom I have included costs under the usual heads of S (land); C (cost of establishment) and e (cost of annual maintenance); but I have added B (cost of brashing and cleaning) as in practice this proves to be a major cost.

All the costs incurred in growing timber must be included under one or another of these heads, S , C , B , and e . When applying the actual results of accountancy and costing to these calculations, it is necessary to make a classification of all costs and to distribute the various items under these heads. The following list shows the general classification I have used.

- S. Cost of land.* Price paid for land; cost of inspection and transfer; permanent fences; road-making; major drainage schemes and prevention of erosion. Building or purchase of houses for staff.
- C. Cost of establishment.* Preparation of ground; temporary fencing; draining; plants and planting; weeding for as many years as is necessary; beating up, including replanting after fire, in so far as this is not covered by insurance.
In practice these costs are spread over 3 or 4 years, though the main items come in the first year; in order to simplify calculations they are all debited in the first year.
- B. Cost of brashing and cleaning.* Brashing and cleaning as required before the first thinning. If the first remunerative thinning is later than 20 years, B is charged at 20 years.
- e. Annual maintenance.* Tithes, land tax, maintenance of fences, roads, drains, including cutting observation paths. Protection against fire, rabbits, and other pests, including extermination of rabbits before planting and maintenance (but not initial erection) of rabbit fencing. Net shooting rents can be credited to this item.

Some forest economists include all *overheads* in e . This swells e to an unwieldy figure and tends to conceal the true costs of operations. I prefer to calculate them separately and allocate them to operations. e , like other operations, will still bear its share of overheads, as allocated in the next section, but only this share.

3. *Overheads.*

Overheads constitute a large part of the costs of forestry, and there is no accepted method of applying them in calculations dealing with forest finance. Considerable experience in this connexion has been gained in the costings kept by the Woodlands Research Department of The Dartington Hall Trustees, and, in the absence of any better alternative, I here use the methods which have now been adopted as their practice.

Overheads fall into three general classes:

- (a) *Unallocated labour costs.* Employer's contribution to insurances, pension schemes, employer's liability. Maintenance and rates on cottages, less

rents charged. Pay for holidays and wet time. Transport of men to and from work. Purchase and maintenance of hand tools, and of other tools if they are not separately charged.

- (b) *Supervision, management, and administration.* Salaries and wages paid for supervision and management, with their overheads. Travelling expenses and housing of supervisory staff. Pension contributions for supervisory staff. Office expenses. Subscriptions and miscellaneous.
- (c) *Area or sectional expenses.* Tithes, land tax, rates. Fire insurance on woods. Insurance of lorries, &c. Depreciation on vehicles and machines. Tax on vehicles.

In preparing costings of specific operations these overheads have to be charged in one way or another. At Dartington they are split up and charged

- (i) partly as a percentage which is added to the cost of *Wages*;
- (ii) partly as a percentage which is deducted from gross receipts from *Sales*;
- (iii) partly to *Sectional or Area Accounts*.

To (i) are allocated the whole of class (a), and a considered proportion of class (b) based on an analysis of the share which is mainly concerned with the control of labour.

To (ii) are allocated the remainder of class (b), i.e. the share which is mainly concerned with the sale of products.

To (iii) are allocated the whole of class (c). For instance, all lorry charges, including insurance, depreciation, and tax, are charged to vehicles, and operations are charged at an appropriate rate per hour for the use of the vehicles. Tithes, fire insurance, &c., are charged to annual maintenance.

The total cost of overheads is calculated annually or every six months; for the subsequent period, costings are worked out with the percentage overheads calculated for the previous period. At the present time they are 30 per cent. on gross wages and 11 per cent. on gross sales.

4. *The present costs of operations.*

These costs are based on present wages, i.e. a minimum of 90s. a week.

S. Cost of land.

The cost of land purchased by the Forestry Commission to 1929, including expenses of acquisition and legal expenses, was £2. 10s. 10d. per acre (8). To this must be added improvements such as fencing, road-making, main drainage, and houses. It is likely that £4 per acre is a suitable total. Land prices have not changed very much during the last 100 years, though cost of improvements has increased. This value is regarded as fixed throughout the period.

C. Cost of establishment.

(a) *Preparation of ground.* This is an extremely variable cost. Assuming, as an average, land which has been recently felled, but needs trimming, burning brush, and a little draining, appropriate figures would be £3 for Scots pine and £6 for

other conifers. All this is wages; adding 30 per cent. for overheads, these figures become £4 and £8.

(b) *Fencing*. This depends on the size and shape of the area; some areas do not need fencing. Assume, as average, a square containing 10 acres. The side of this square is 10 chains, and the total surround is 40 chains or 880 yards, i.e. 88 yards per acre. On this basis the cost per acre, estimated on costings at Dartington, would be:

	Labour	Materials
	£	£
33 stakes at 8d. each for preparation and haulage	1.1	..
Labour erecting at 7d. per yd.	2.6	..
Netting 88 yds. at 49s. 6d. per 50 yds., plus top wire and staples	..	4.4
Overheads, 30 per cent. on labour	1.1	..
	<u>4.8</u>	<u>4.4</u>
Total		£9.2

(c) *Plants*. Assume that transplants are grown in own nursery and can be delivered to wood at the present controlled prices ex nursery. The cost per acre is:

	£
SP. at 4½ ft., 2,200 plants at 81s. per 1,000	8.1
EL. at 4½ ft., 2,200 plants at 99s. per 1,000	10.9
NS. at 4½ ft., 2,200 plants at 99s. per 1,000	10.9
DF. at 6 ft., 1,200 plants at 108s. per 1,000	6.5

(d) *Planting*.

	£	£
		<i>with overheads</i>
SP. 450 per man-day—cost per acre	4.0	5.2
EL. 350 per man-day—cost per acre	5.2	6.8
NS. 350 per man-day—cost per acre	5.2	6.8
DF. 300 per man-day—cost per acre	3.3	4.3

(e) *Weeding*. The average cost in 1947 of weeding 41 areas, totalling 208 acres, belonging to Dartington Woodlands Ltd. was £5.1 per acre. This includes overheads at 30 per cent. Correcting for a wage of 90s. in place of 80s., this cost becomes £5.7 per acre. Allowing 1½ weedings for Scots pine and 3 weedings for other species, the cost per acre would be:

	£
Scots pine	8.6
Other conifers	17.1

(f) *Beating up*. This is a very variable cost. Allowing for the fact that some plantations have to be completely replanted, an average should be allowed of 15 per cent. of original plants and planting. The cost per acre, including overheads, is:

	£
SP. (8.1+5.2)×0.15 = 2.0	
EL., NS. (10.9+6.8)×0.15 = 2.7	
DF. (6.5+4.3)×0.15 = 1.6	

(g) The *total cost* of establishing 1 acre, including overheads, works out at:

	SP.	EL. and NS.	DF.
	£	£	£
(a) Preparing ground . . .	4	8	8
(b) Fencing	9·2	9·2	9·2
(c) Plants	8·1	10·9	6·5
(d) Planting	5·2	6·8	4·3
(e) Weeding	8·6	17·1	17·1
(f) Beating up	2·0	2·7	1·6
Total	£37·1	£54·7	£46·7

These figures appear high. It should be noted, however, that (a) they are calculated with a wage of 90s. a week, (b) they include weeding and beating up, (c) they include overheads. *Mutatis mutandis*, they compare fairly accurately with pre-war estimates. In 1929 the cost was given by the Forestry Commission as £12. 13s. The wage was then 31s. 9d. and is now 90s. Correcting to the present wage costs, £12. 13s. would become £34. The difference between this and the costs calculated above can be accounted for by the extra cost in private woodlands of planting smaller areas and planting old woodland instead of bare land.

B. Cost of brashing and cleaning.

Available costings are insufficient to give reliable figures of the costs of these operations for various species. The following estimates of cost per acre are based on general experience.

	Brashing	Cleaning	Overheads	Total
	£	£	£	£
SP.	5	2	2·1	9·1
EL.	2·5	4	1·9	8·4
NS.	5	4	2·7	11·7
DF.	5	4	2·7	11·7

c. Cost of annual maintenance.

This is a difficult figure to determine. It has to include all costs which are not already carried either in the above operations or in overheads which are charged to wages and sales.

In making an estimate I have assumed that the equivalent of 1 man might maintain fences and drains, and do those road repairs that are not charged to particular operations, on 300 acres. His wage with insurances would be about £250 per annum, and the additional cost of stone, gates, wire, &c., together with overheads, would bring this charge to about £1·2 per acre per annum.

Fire protection costs the Forestry Commission about 5s. per acre per annum. Private woodlands, being smaller and more scattered, require less protection

and those which are particularly liable to fire hazard should be insured. In the woods belonging to Dartington Woodlands Ltd. the cost of insurances and protection is between 1*s.* and 2*s.* per acre per annum. On many estates it would be more.

Tithes are not usually payable on woods unless they were coppice in 1836. The average cost per acre per annum of tithes and land tax is probably not more than 6*d.* Rates are not now chargeable in England and Wales, but were chargeable before 1929.

Making allowance for shooting rents, which can be credited to this item, it appears that a fair estimate for *e* is £1.1 per acre per annum.

5. *Money yield tables.*

The cost of making a normal forest is reduced by such net receipts as are obtained from thinnings. The amounts which may be expected from these thinnings are determined from money yield tables which are constructed from volume yield tables extended with money values per cubic foot of the thinning at each age.

Money yield tables which have been worked out for the second quality of Scots pine, European larch, Norway spruce, and Douglas fir are displayed in Appendix II, where notes explaining the figures are given.

We are concerned here with the *net* receipts from thinnings, whereas the figures given in Appendix I are the *gross* receipts. The appropriate figures for these thinnings would be the amounts for which they can be sold standing. As, however, there is usually no market for standing thinnings, prices have to be based on experience of the net amounts which may be received for thinnings after money has been spent on felling, extracting, and even converting them. Few reliable data are available on which to base these figures, but we have indications which afford valuable evidence.

The first thinning in a plantation is not generally remunerative, although examples could be cited in which, under particularly favourable conditions, usually with quite small plantations, a first thinning may be profitable where there is a good market for rustic poles. A good market is also provided for small thinnings by paper and pulp factories, but the railway rate on pulpwood is too high for this to have an important influence on national statistics. Examples could be quoted to show that, under conditions which may be regarded as average conditions for Britain as a whole, the first, and often the second, thinning results in a loss of money.

The chief product of the next thinning would be pitprops. This should yield a profit if extraction is not too expensive. The cost per cubic foot of felling, extracting, and converting poles for pitprops becomes progressively less as the poles become larger; so, for any fixed price per cubic foot for pitprops, it is easier to make a profit with large than with small thinnings. Even at later ages the profit from thinnings is limited more by the controlled prices of pitprops than by the controlled standing or felled prices of round timber. As the price of unpeeled coniferous pitprops, f.o.r., varies from about 1*s.* 11*d.* to 3*s.* 2½*d.* per

cubic foot, whereas the maximum controlled price of coniferous thinnings is 9*d.* up to 6 inches Q.G. for larch and up to 8 inches Q.G. for other conifers, it might be thought that the price of pitprops was high enough to allow growers to obtain the full controlled price for standing thinnings. And on easily worked level ground it may be. But most of the land which is devoted to forestry is land which is too poor, too steep, or too remote for agriculture; and the steep and remote areas are usually very poorly supplied with roads and are frequently far from a station. There are favourably sited plantations in which the production of pitprops is reasonably cheap; but the average costs are very high.

My own experience leads me to think that in general the thinnings which are taken before the average size of the main crop is 6 inches Q.G., B.H., may just pay for themselves but do not, collectively, yield a profit. Any net gain on the latest thinnings before this size is reached is neutralized by the loss on the earlier thinnings. Consequently, in the yield tables, I have assumed that thinnings begin to be remunerative when the main crop reaches 6 inches Q.G., B.H. I have then given them an initial value of 2*d.* per cu. ft.

When the quarter-girth of the main crop reaches 10 inches Q.G. the thinnings are of an economic size for pitprops. There may then be a market for them standing. But, as thinnings are more expensive to fell and extract than whole woods, they are unlikely to sell for the full maximum price and I have given them a price of 2*d.* per cu. ft. below the maximum price.

The prices of intervening thinnings have been spaced out evenly between these two prices.

The final crop has been priced at the maximum standing price. This price is 2*d.* per cu. ft. less than the price shown in Table II, since this table gives the maximum price felled at stump instead of the standing price which is 2*d.* per cu. ft. lower.

It has been assumed that volume production is 80 per cent. of the yield tables and 11 per cent. has been deducted from money yield to allow for overheads.

6. *Method of calculating the cost of a normal forest.*

The area of the normal forest is assumed to be 100 acres. In order to simplify calculations, the cost has been worked out as though all operations were carried out at 10-yearly intervals. Thus, for a normal forest of Scots pine on a rotation of 100 years, the calculation is based on 10 acres planted in 1853, brashed and cleaned in 1873, and thinned in 1883, 1893, &c., plus 10 acres planted in 1863, and 10 in each of the years 1873, 1883, 1893, 1903, 1913, 1923, 1933, 1943. The cost of each 10 acres has been worked out separately. The sum of these costs is an approximation to the cost to 1948 of a normal forest of 1 acre planted in each year from 1848 to 1947.

An allowance for the change in wages over the period covered by the calculations has been made by using the wage index on p. 41 of MacGregor's 'Labour Costs in English Forestry since 1824' (6). An appropriate wage index has been worked out for each of the years 1853, 1863, 1873, 1883, 1893, 1903, 1913, 1923, 1933, 1943 by taking the average for the decade. Thus the index for 1933 is the

average of the indices for the years 1928 to 1937. These average indices, corrected to 1948 (90s.) as 100, are as follows:

1853 . . . 11	1903 . . . 16
1863 . . . 13	1913 . . . 21
1873 . . . 14	1923 . . . 39
1883 . . . 15	1933 . . . 35
1893 . . . 15	1943 . . . 63

Thus the cost of establishment of Scots pine which in 1948 is £37.1 is taken as 37.1×0.11 or £4.1 in 1853.

The value of e has been corrected in the same manner but has been regarded as constant during each decade. Thus from 1888 to 1897 it was 1.1×0.15 or £0.16 each year. The value of past thinnings has been reduced in the same manner.

All costs have been brought forward at 3 per cent. compound interest from the date when they were incurred to 1948. Similarly all receipts from thinnings have been brought forward and have been deducted from the costs.

An example of this method of working is given in Appendix IV.

The calculated costs of a 100-acre normal forest of Scots pine, Quality II, European larch, Quality II, Norway spruce, Quality II, and Douglas fir, Quality II are, respectively, £10,394, £8,361, £7,656, and £5,515.

V. THE INCREASE IN PRICES REQUIRED TO EARN 4 PER CENT. ON SECOND-QUALITY SITES.

We are now in a position to estimate the change in prices which would be required to enable the owner of a normal forest on a second-quality site of each of these species to earn a rate of 4 per cent. on the capital cost of his forest. The figures are displayed in Table IV.

Column 2 shows the cost of a normal forest of 100 acres, calculated in the manner explained in the last section. Columns 3 and 4 show the gross income and the net annual income (or profit and loss) which may be earned from these forests at present prices; these figures are taken from Table III. Column 5 shows the net income which would be required to earn 4 per cent. on the cost value of the forest, and column 6 the amount by which this income exceeds the income in column 4. In order to earn 4 per cent. it would be necessary for the gross income in column 3 to be raised by this amount; and since all this income (apart from the sale of very small thinnings) is based on maximum prices, it would be necessary for maximum prices to be raised by the same percentage, i.e. $\text{column 6} \div \text{column 3} \times 100$. This percentage is shown in column 7.

The conclusion reached from all these calculations is that, in order to enable the owners of normal forests on second-quality sites to earn 4 per cent. on their investment, it would be necessary to raise the price of Scots pine by 147 per cent., European larch by 44 per cent., Norway spruce by 42 per cent., and Douglas fir by 10 per cent. For the four forests taken together the necessary rise is 44 per cent. If prices were raised by this amount, and if a fresh set of calculations were made using the new prices as a basis, different figures would be obtained for the

cost values of the normal forests. The reason for this is that in calculating the cost value of a normal forest the thinnings have been valued at present prices corrected to earlier periods in proportion to the wage index. So the value attached to these past thinnings would have to be altered. The alterations in the cost values of normal forests are, however, very small, being a 1·7 per cent. reduction for Scots pine, 5·5 per cent. for European larch, 4·3 per cent. for Norway spruce, and 5·8 per cent. for Douglas fir. Making allowance for these reductions, a slightly lower net income is required to earn 4 per cent. on the capital values. It may be shown that, if allowance is made for this source of inaccuracy, a rise of 42 per cent. in timber prices (instead of 44 per cent.) would allow a return of 4 per cent. on capital.

TABLE IV. *Changes in prices which are necessary to enable normal forest to earn 4 per cent.*

<i>Species and site quality</i> (1)	<i>Cost of normal forest of 100 acres</i> (2)	<i>Calculated gross inc. from Table III, Col. 5</i> (3)	<i>Calculated profit or loss from Table III, Col. 10</i> (4)	<i>Income re- quired to yield 4 % on cost of normal forest. Col. 2 × 0·04</i> (5)	<i>Increase in income required. Col. 5 minus Col. 4</i> (6)	<i>% increase on prices required. Col. 6 ÷ Col. 3 × 100</i> (7)
	£	£	£	£	£	
Scots pine II (<i>Pinus sylvestris</i> L.) . . .	10,394	315	—48	416	464	147
European larch II (<i>Larix decidua</i> Mill.) . . .	8,361	536	+100	334	234	44
Norway spruce II (<i>Picea abies</i> Karst.) . . .	7,656	643	+34	306	272	42
Douglas fir II (<i>Pseudotsuga taxifolia</i> Brit.) . .	5,515	908	+126	221	95	10
Sum of four forests . . .	31,926	2,402	212	1,277	1,065	44

VI. DISCUSSION.

1. *The method of testing the reasonableness of controlled prices.*

In forest accounts it is notoriously difficult to distinguish between capital and income. Most of a forester's income is derived from felling mature trees which, until they are felled, are regarded as a capital asset. And a period of heavy felling, during which valuable assets are realized, must usually be followed by a period of reconstruction during which expenditure exceeds receipts, so that some of the capital which was previously realized must be reinvested in the forest.

A normal forest is the forester's ideal, both sylviculturally and in relation to management. In a normal forest, which is worked on a system of sustained yield, the timber stocking, and (if prices are unchanged) the capital value, remain

constant from year to year. So the net proceeds derived from running the forest can legitimately be regarded as profit and should be realizable in perpetuity. Consequently, with a normal forest there is a sound distinction between capital (the land and normal stocking) and profit (the net income derived from the forest). In all text-books on forest finance this view is emphasized.

In practice no forest is ideally normal; and in Britain heavy fellings during two world wars have frustrated the best endeavours that foresters may have made to achieve normality. So there are no actual examples of net income from normal forests in Britain which can be used for assessing reasonable prices. But the method of building up the total costs of growing timber from the summation of individual operational costs, with appropriate rates of compound interest, has been employed by forest economists ever since the subject began to be developed nearly a century ago and has continued to be their normal practice.

It is claimed, therefore, that the method adopted in this paper is sound in theory and is in accordance with the traditions of forest economics. If complete cost accounts covering long periods were available for woodlands, such accounts would be of great value in providing more accurate data of operational costs, but they would not obviate the necessity of using the theoretical normal forest as a basis for estimating reasonable prices.

2. *What increase in prices is required to make forestry remunerative?*

Forestry is more profitable on good quality than poor quality sites. This is due to faster growth and to the fact that more remunerative species can be grown on good land. The influence of species and soil quality on the cost of producing timber is clearly shown in Table XLI of my *Economics of Forestry* (5), from which it may be seen that it costs more than three times as much to grow a 30 cu. ft. tree of Scots pine as it costs to grow a tree of the same size of Douglas fir. Also it costs about twice as much to produce timber on a third-quality site of Scots pine as on a first-quality site.

It follows from this that with any given set of prices forestry may be remunerative on good soil, but unremunerative, or at any rate much less profitable, on poor soil. With low prices much potential forest land becomes sub-marginal for economic forestry; and, with rising wages, still more land will become sub-marginal unless operations can be cheapened by mechanization or other means.

If Government fixes prices it should be influenced, when determining the rates, by the consideration of how much timber it wants to have grown. If it wishes private foresters to plant up poor land as well as good, it must either fix prices at a sufficiently high level or in some other way subsidize cultivation.

The results which are shown in Table IV of this paper are based on the second-quality sites of Scots pine, European larch, Norway spruce, and Douglas fir. These species were chosen because they are the only species for which sufficient data are given in the *Forestry Commission Yield Tables* (3). They are typical of the plantations in Britain which are at present yielding timber and are appropriate for our present purpose. The average site quality of coniferous plantations

in Britain is, however, rather below Quality II, although, until an adequate census has been taken, no accurate information will be available as to what the average is. It follows from this that, even if prices were raised by 42 per cent., the *average* plantation would still yield rather less than 4 per cent. on its capital value as calculated in this paper.

There is a further reason for believing that, even under good management, forestry is rather less profitable than is suggested by the figures in Table IV. In assessing figures for which few reliable data are available I have been anxious not to overstate my case and have tended to err on the side of making forestry appear more profitable than it is, rather than the contrary. The following are examples of this.

- (a) In calculating the gross annual income in Table III it is assumed that all thinnings could be sold at the maximum price for round timber at stump. Owing to the present price of pitprops, such thinnings do not generally fetch maximum prices.
- (b) In estimating the gross expenditure in Table III the allowance for overheads and purchases is 30 per cent. of gross wages. It may be just possible to restrict such costs to this amount in woods where all timber is sold at stump; but, in general, these costs are likely to be higher.
- (c) In Section IV. 4 *e* the annual cost of maintenance is assessed at £1.1 per acre. It is impossible to obtain data on which to base this figure without detailed analyses of estate accounts. It is likely, however, that the cost is considerably higher in most well-managed woods.
- (d) I have probably taken insufficient account of the downright mistakes and failures which occur even in the best managed woods.

It is important to note that, owing to the large size of their forests and the fact that most of their plantations have been made on bare land, the average operational costs in Forestry Commission work are likely to be rather lower than the corresponding costs in private woods. The overhead charges are, however, proportionately higher in State forests and this is likely to offset any saving in wages.

3. *Should controlled prices change when wages change?*

The second of the 'principles involved in fixing prices', which were discussed in Section II of this paper, is that 'prices must be high enough to make the continued cultivation of woodlands remunerative'. The test of this is whether at any time the maintenance of a normal forest on a system of sustained yield provides an appropriate net income.

If wages rise the cost of maintaining a normal forest will be increased. It is therefore necessary that prices should be raised if the net income is to remain the same. This does not mean that prices must rise in proportion to wages. If they did then the net profit would also rise.

It may be shown from Table III that if maximum prices were raised by 42 per cent. and, subsequently, wages and other costs were raised by 10 per cent., the

following rises in timber prices would be required in order that the net income should remain the same as before: Scots pine II, 8·7 per cent.; European larch II, 6·0 per cent.; Norway spruce II, 7·0 per cent.; Douglas fir II, 6·4 per cent. For a forest composed equally of these species the required rise would be 6·7 per cent.

APPENDIX I

Gross income from normal forest of 'r' acres

On the assumption that plantations at all ages are fully stocked and that maximum prices, felled at stump, are obtained for all timber and thinnings from plantations in which the Quarter Girth, Breast Height (Q.G., B.H.) of main crop is not less than 5 inches.

For explanations see Section III, 2.

Scots Pine (England) r = 100. (Pinus sylvestris L.)

Age	Quality I				Quality II				Quality III			
	Q.G., B.H. main crop	Vol.	Price	Value	Q.G., B.H. main crop	Vol.	Price	Value	Q.G., B.H. main crop	Vol.	Price	Value
	in.	Lin. ft.	d.	£	in.	Lin. ft.	d.	£	in.	Lin. ft.	d.	£
20	..	3,000	$\frac{1}{2}$	6	..	2,000	$\frac{1}{2}$	4	..	..	..	..
25	..	4,000	$\frac{3}{4}$	12	..	3,000	$\frac{3}{4}$	9	..	1,500	$\frac{1}{2}$	3
30	..	4,000	1	17	..	3,500	1	15	..	2,500	$\frac{3}{4}$	8
	cu. ft.											
35	5 $\frac{1}{4}$	135	11	6	..	4,000	1 $\frac{1}{2}$	21	..	3,000	1	12
						cu. ft.						
40	6 $\frac{1}{4}$	170	11	8	5 $\frac{1}{4}$	120	11	5	..	3,500	1 $\frac{1}{2}$	18
										cu. ft.		
45	7	195	11	9	6	140	11	6	5	85	11	4
50	7 $\frac{3}{4}$	210	11	10	6 $\frac{3}{4}$	150	11	7	5 $\frac{3}{4}$	95	11	4
55	8 $\frac{1}{2}$	210	11	10	7 $\frac{1}{2}$	160	11	7	6 $\frac{1}{4}$	105	11	5
60	9	225	11	10	8	170	11	8	7	115	11	5
65	9 $\frac{3}{4}$	220	11·1	10	8 $\frac{3}{4}$	175	11	8	7 $\frac{1}{2}$	120	11	6
70	10 $\frac{1}{4}$	220	11·4	10	9 $\frac{1}{2}$	180	11	8	8 $\frac{1}{4}$	130	11	6
75	11	210	11·8	10	10	180	11·2	8	8 $\frac{3}{4}$	130	11	6
80	11 $\frac{1}{2}$	200	12·2	10	10 $\frac{1}{2}$	175	11·5	8	9 $\frac{1}{4}$	130	11	6
85	12	190	12·5	10	11	165	11·8	8	9 $\frac{3}{4}$	130	11·1	6
90	12 $\frac{1}{2}$	180	12·8	10	11 $\frac{1}{2}$	155	12·2	8	10 $\frac{1}{4}$	125	11·4	6
95	13	170	13·1	9	12	145	12·5	8	10 $\frac{3}{4}$	115	11·7	6
100	13 $\frac{1}{4}$	5,890	14·2	348	12 $\frac{1}{4}$	5,260	13·7	300	11 $\frac{1}{4}$	4,495	13·2	247
		8,425		505		7,175		438		5,775		348
Total value				£505	Total value			£438	Total value			£348
" " less 28% . . .				£364	" " less 28% . . .			£315	" " less 28% . . .			£251
				cu. ft.				cu. ft.				cu. ft.
Total volume				8,425	Total volume			7,715	Total volume			5,775
" " less 20% . . .				6,740	" " less 20% . . .			5,740	" " less 20% . . .			4,620

Age	Quality I				Quality II				Quality III				Quality V			
	Q.G., B.H. Main crop	Volume	Price	Value	Q.G., B.H. Main crop	Volume	Price	Value	Q.G., B.H. Main crop	Volume	Price	Value	Q.G., B.H. Main crop	Volume	Price	Value
15	in.	Lin. ft.	d.	£	in.	Lin. ft.	d.	£	in.	Lin. ft.	d.	£	in.	Lin. ft.	d.	£
20	..	4,500	1'0	19	..	3,500	1'0	15	..	2,500	1'0	5	..	..	..	..
	..	6,000	1'1	37	..	4,000	1'1	21	..	2,800	1'0	12	..	..	..	..
25	5	cu. ft.	11'0	7	..	4,000 = 120 cu. ft.	1'1	25	..	3,200	1'1	17	..	1,200	1'1	2
30	6	190	11'0	9	5	cu. ft.	11'0	7	..	3,600	1'1	22	..	1,800	1'1	6
35	6 1/2	220	11'7	11	6	180	11'0	8	5	145	11'0	7	..	2,800	1'0	12
40	7 1/2	245	12'3	13	6 1/2	200	11'7	10	5 1/2	160	11'0	7	..	3,200	1'1	17
45	8 1/2	270	13'1	15	7 1/2	220	12'3	11	6 1/2	175	11'5	8	..	4,000 = 75 cu. ft.	1'1	25
50	9	290	14'0	17	8 1/2	240	13'1	13	7 1/2	185	12'1	9	5	cu. ft.	11'0	4
55	9 1/2	315	14'8	19	8 1/2	250	13'7	14	7 1/2	195	12'6	10	5 1/2	90	11'0	5
60	10 1/2	330	15'4	21	9 1/2	260	14'5	16	8 1/2	205	13'4	11	6 1/2	100	11'3	5
65	10 1/2	325	15'8	21	10	265	15'1	17	9	215	14'0	13	7	115	11'9	6
70	11 1/2	290	16'5	20	10 1/2	260	15'8	17	9 1/2	215	14'8	13	7 1/2	125	12'3	7
75	12	250	16'9	18	11 1/2	230	16'2	16	10 1/2	200	15'6	13	8 1/2	140	13'1	8
80	12 1/2	6,280	18'8	492	11 1/2	5,350	18'2	406	11	4,460	17'6	327	8 1/2	2,830	15'5	183
		9,160		719		7,725		596		6,155		474		3,620		280
	Total value			£719	Total value			£596	Total value			£474	Total value			£280
	" less 28%			£518	" less 28%			£429	" less 28%			£341	" less 28%			£202
	Total volume			9,160 cu. ft.	Total volume			7,725 cu. ft.	Total volume			6,155 cu. ft.	Total volume			3,620 cu. ft.
	" less 20%			7,328 cu. ft.	" less 20%			6,180 cu. ft.	" less 20%			4,924 cu. ft.	" less 20%			2,896 cu. ft.

APPENDIX I (cont.)
Norway Spruce $r = 70$ (*Picea abies* Karst.)

Age	Quality I			Quality II			Quality III			Quality V		
	Q.G., B.H. Main crop	Volume	Price	Value	Q.G., B.H. Main crop	Volume	Price	Value	Q.G., B.H. Main crop	Volume	Price	Value
15	in.	Lin. ft.	d.	£	in.	Lin. ft.	d.	£	in.	Lin. ft.	d.	£
20	..	2,000	$\frac{1}{2}$	4	..	1,000	$\frac{1}{2}$	2	..	..	..	..
25	..	3,750	$\frac{3}{4}$	12	..	3,000	$\frac{3}{4}$	9	..	2,000	$\frac{1}{2}$	4
	..	5,000	1.0	21	..	4,000	1.0	17	..	2,800	$\frac{3}{4}$	9
30		cu. ft.				cu. ft.						
	5 $\frac{1}{2}$	410	11.0	19	5.0	220	11.0	10	..	3,600	1.0	15
35	7	440	11.0	20	6 $\frac{1}{2}$	300	11.0	14	5	cu. ft.		
40	8 $\frac{1}{2}$	485	11.0	22	7 $\frac{1}{2}$	320	11.0	15	6 $\frac{1}{2}$	180	11.0	8
45	9 $\frac{1}{2}$	490	11.0	22	8 $\frac{1}{2}$	350	11.0	16	7 $\frac{1}{2}$	210	11.0	10
										240	11.0	11
50	10 $\frac{1}{2}$	470	11.5	23	9 $\frac{1}{2}$	350	11.0	16	8 $\frac{1}{2}$	270	11.0	12
55	11 $\frac{1}{2}$	445	12.2	23	10 $\frac{1}{2}$	340	11.5	16	9 $\frac{1}{2}$	280	11.0	13
60	12 $\frac{1}{2}$	415	12.8	22	11 $\frac{1}{2}$	330	12.2	17	10 $\frac{1}{2}$	260	11.4	12
65	13 $\frac{1}{2}$	345	13.2	19	12 $\frac{1}{2}$	315	12.8	17	11	240	11.8	12
70	14	9,280	14.6	565	13 $\frac{1}{2}$	8,050	14.2	476	11 $\frac{1}{2}$	6,930	13.4	387
		12,780		772		10,575		625		8,610		493
	Total value			£772	Total value			£625	Total value			£493
	" less 28%			£556	" less 28%			£450	" less 28%			£355
	Total volume			12,780 cu. ft.	Total volume			10,575 cu. ft.	Total volume			8,610 cu. ft.
	" less 20%			10,224 cu. ft.	" less 20%			8,460 cu. ft.	" less 20%			6,888 cu. ft.
	Total value			£287	Total value			£287	Total value			£287
	" less 28%			£207	" less 28%			£207	" less 28%			£207
	Total volume			5,195 cu. ft.	Total volume			5,195 cu. ft.	Total volume			5,195 cu. ft.
	" less 20%			4,156 cu. ft.	" less 20%			4,156 cu. ft.	" less 20%			4,156 cu. ft.

APPENDIX I (cont.)

Douglas Fir $\tau = 50$ (*Pseudotsuga taxifolia* Brit.)

Age	Quality I				Quality II				Quality III				Quality IV			
	Q.G., B.H. Main crop	Volume	Price	Value	Q.G., B.H. Main crop	Volume	Price	Value	Q.G., B.H. Main crop	Volume	Price	Value	Q.G., B.H. Main crop	Volume	Price	Value
15	in. ..	Lin. ft. 2,800	d. 11.0	£ 12	in. ..	Lin. ft. ..	d. ..	£ ..	in. ..	Lin. ft. ..	d. ..	£ ..	in. ..	Lin. ft. ..	d. ..	£ ..
20	5½	cu. ft. 430	11.0	20	..	8,000 = 225 cu. ft.	1.0	33	..	8,000	1.0	33	..	..	..	..
25	7½	590	11.0	27	6½	cu. ft. 435	11.0	20	5½	cu. ft. 305	11.0	14	..	14,000	1.0	58
30	9	625	11.0	29	8½	520	11.0	24	7½	420	11.0	19	6½	cu. ft. 305	11.0	14
35	10½	640	11.7	31	10	545	11.2	25	9	440	11.0	20	8	355	11.0	16
40	12½	595	12.6	31	11½	545	12.2	28	10½	450	11.5	22	9½	390	11.0	18
45	13½	570	13.5	32	13	520	13.1	28	12	485	12.5	25	11	410	11.8	20
50	15½	8,440	15.1	531	14½	7,650	14.8	472	13½	6,885	14.2	407	12½	6,145	13.7	351
		11,890		713		10,440		630		8,985		540		7,805		477
	Total value	..	..	£713	Total value	..	..	£630	Total value	..	..	£540	Total value	..	..	£477
	" less 28%	..	..	£513	" less 28%	..	..	£454	" less 28%	..	..	£389	" less 28%	..	..	£343
	Total volume	..	..	11,890 cu. ft.	Total volume	..	..	10,440 cu. ft.	Total volume	..	..	8,985 cu. ft.	Total volume	..	..	7,805 cu. ft.
	" less 20%	..	..	9,512 cu. ft.	" less 20%	..	..	8,352 cu. ft.	" less 20%	..	..	7,188 cu. ft.	" less 20%	..	..	6,244 cu. ft.

APPENDIX II

The following money yield tables for the second quality of Scots pine, European larch, Norway spruce, and Douglas fir have been constructed from the *Forestry Commission Yield Tables* (3), with prices calculated in the manner described in Section IV. 5. The following notes explain how the figures in each column are derived.

- Col. 2. Quarter-girth, breast height, from Yield Table.
- „ 3. Quarter-girth, mid-timber height, derived from col. 2 in accordance with Table II.
- „ 4. Volume of main crop from Yield Table.
- „ 5. Volume reduced by 20 per cent. to allow for 80 per cent. efficiency.
- „ 6. Maximum price, standing, derived from Table II. (2d. per cu. ft. is deducted for difference between standing and felled prices.)
- „ 7. Maximum price less 11 per cent. to allow for overheads on sales.
- „ 8. Value of volume in col. 5 at price in col. 7.
- „ 9 and 10. Quarter-girth, breast height and mid-timber height, of thinnings from Table II.
- „ 11. Volume of thinnings from Yield Table.
- „ 12. Volume reduced by 20 per cent. to allow 80 per cent. efficiency.
- „ 13. Price of thinnings: see Section IV. 5.
- „ 14. Price reduced by 11 per cent. to allow for overheads on sales.
- „ 15. Value of volume in col. 12 at price in col. 14.
- „ 16. Values arranged at ten-yearly intervals for ease of calculation.
- „ 17. Value of final yield if wood is clear-felled at this age.

APPENDIX II (cont.)

Scots Pine (England) Quality II: Money Yield Table (*Pinus sylvestris* L.)
Realizable Standing Prices

Main crop										Thinnings						Final Yield (17)
Age Q.G., B.H. (1)	Q.G., M.T.H. (2)	Q.G., M.T.H. (3)	Vol. (4)	Vol. less 20% (5)	Max. price (6)	Max. price less 11% (7)	Value (8)	Q.G., B.H. (9)	Q.G., M.T.H. (10)	Vol. (11)	Vol. less 20% (12)	Estd. sale price (13)	Estd. sale price less 11% (14)	Value (15)	Value at 10 yr. intervals (16)	
	in.	in.	cu. ft.	cu. ft.	d. per cu. ft.	d. per cu. ft.	£	in.	in.	cu. ft.	cu. ft.	d. per cu. ft.	d. per cu. ft.	£	£	
40	5½	4·2	2,110	1,690	..	..	..	4·0	3·5	120	95	..	..	..	..	
45	6	4·7	2,520	2,020	..	..	..	4·7	3·9	140	110	..	..	..	..	
50	6½	5·2	2,890	2,310	..	..	..	5·4	4·3	150	120	2·0	1·8	0·9	1·5	
55	7½	5·6	3,270	2,620	..	..	..	6·1	4·7	160	130	2·5	2·2	1·2	..	
60	8	5·9	3,550	2,840	9·0	8·0	95	6·5	5·0	170	135	3·5	3·1	1·7	3·4	
65	8½	6·4	3,820	3,060	..	..	..	7·3	5·5	175	140	4·5	4·0	2·3	..	
70	9½	6·9	4,060	3,250	9·9	8·8	119	8·0	5·9	180	145	5·5	4·9	3·0	5·9	
75	10	7·2	4,300	3,440	..	..	..	8·4	6·2	180	145	6·5	5·8	3·5	..	
80	10½	7·5	4,470	3,580	10·7	9·5	143	8·9	6·5	175	140	7·5	6·7	3·9	7·6	
85	11	7·8	4,670	3,740	11·0	9·8	153	9·3	6·8	165	130	7·8	6·9	3·7	..	
90	11½	8·1	4,850	3,880	11·3	10·1	163	9·8	7·1	155	125	8·2	7·3	3·8	7·4	
95	12	8·4	5,030	4,030	11·6	10·3	173	10·3	7·3	145	115	8·5	7·6	3·6	..	
100	12½	8·5	5,130	4,100	11·7	10·4	178	10·5	7·5	130	105	10·6	9·4	4·1	5·9	

APPENDIX II (cont.)
European Larch, Quality II: Money Yield Table (Larix decidua Mill.)
Realizable Standing Prices

Main crop										Thinnings						
Age (1)	Q.G., B.H. (2)	Q.G., M.T.H. (3)	Vol. (4)	Vol. less 20% (5)	Max. price (6)	Max. price less 11% (7)	Value (8)	Q.G., B.H. (9)	Q.G., M.T.H. (10)	Vol. (11)	Vol. less 20% (12)	Estd. sale price (13)	Estd. sale price less 11% (14)	Value (15)	Value at 10 yr. intervals (16)	Final Yield (17)
	in.	in.	cu. ft.	cu. ft.	d. per cu. ft.	d. per cu. ft.	£	in.	in.	cu. ft.	cu. ft.	d. per cu. ft.	d. per cu. ft.	£	£	£
25	4½	3·8	1,520	1,220	..	..	..	3·2	..	120	100	2·0	1·8	0·7	..	..
30	5	4·1	2,100	1,680	..	..	..	3·7	..	150	120	3·2	2·8	1·4	3·2	..
35	6	4·7	2,600	2,080	..	..	..	4·7	3·9	180	140	4·3	3·8	2·2	..	..
40	6½	5·2	3,050	2,440	11·1	9·9	101	5·4	4·3	200	160	5·5	4·9	3·3	6·6	108
45	7½	5·6	3,410	2,730	12·0	10·7	122	6·1	4·7	220	180	6·6	5·9	4·4	..	..
50	8½	6·1	3,700	2,960	12·9	11·5	142	6·7	5·1	240	190	7·8	6·9	5·5	11·0	153
55	8½	6·5	4,000	3,200	13·5	12·0	160	7·3	5·5	250	200	8·9	7·9	6·6	..	..
60	9½	6·9	4,250	3,400	14·2	12·6	179	8·0	5·9	260	210	10·0	8·9	7·8	15·4	194
65	10	7·2	4,510	3,610	14·7	13·1	197	8·5	6·3	265	210	11·1	9·9	8·7	..	..
70	10½	7·6	4,760	3,810	15·4	13·7	217	9·1	6·7	260	210	11·8	10·5	9·2	17·7	235
75	11½	7·9	4,960	3,970	15·8	14·1	233	9·6	6·9	230	180	12·2	10·9	8·2	..	..
80	11½	8·2	5,170	4,140	16·2	14·4	248	10·1	7·2	180	140	14·7	13·1	7·6	11·7	260

APPENDIX II (cont.)
 Norway Spruce, Quality II: Money Yield Table (*Picea abies* Karst.)
 Realizable Standing Prices

Main crop										T binnings						
Age	Q.G., B.H.	Q.G., M.T.H.	Vol. (4)	Vol. less 20% (5)	Max. price (6)	Max. price less 11% (7)	Value (8)	Q.G., B.H.	Q.G., M.T.H.	Vol. (11)	Vol. less 20% (12)	Estd. sale price (13)	Estd. sale price less 11% (14)	Value (15)	Value at 10 yr. intervals (16)	Final Yield (17)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
	in.	in.	cu. ft.	cu. ft.	d. per cu. ft.	d. per cu. ft.	£	in.	in.	cu. ft.	cu. ft.	d. per cu. ft.	d. per cu. ft.	£	£	£
30	5	4.1	2,840	2,270	..	..	..	3.7	..	220	180	2.0	1.8	1.3	2.7	..
35	6½	4.8	3,680	2,950	..	..	..	4.9	4.0	300	240	3.1	2.8	2.8	..	..
40	7½	5.6	4,490	3,590	9.0	8.0	120	6.1	4.7	320	260	4.2	3.7	4.0	8.2	128
45	8½	6.2	5,250	4,200	9.3	8.3	145	7.0	5.3	350	280	5.3	4.7	5.5	..	..
50	9½	6.9	5,890	4,720	9.9	8.8	173	8.0	5.9	350	280	6.4	5.7	6.6	13.1	186
55	10½	7.5	6,450	5,160	10.7	9.5	204	8.0	6.5	340	270	7.5	6.7	7.5	..	..
60	11½	8.1	6,940	5,560	11.3	10.1	234	9.8	7.1	330	260	8.2	7.3	7.9	15.7	250
65	12½	8.7	7,390	5,910	11.8	10.5	258	10.8	7.6	315	250	8.8	7.8	8.1	..	..
70	13½	9.2	7,800	6,240	12.2	10.9	283	11.4	8.0	250	200	11.2	10.0	8.3	12.3	295

Note: Col. 13, Age 30 is given a value of 2d. per cu. ft., although Q.G., B.H., main crop, is less than 6 inches, because of Christmas tree return on early thinnings.

APPENDIX II (cont.)
Douglas Fir, Quality II: Money Yield Table (Pseudotsuga taxifolia Brit.)
 Realizable Standing Prices

Age (1)	Main crop						Thinnings						Final Yield (17)		
	Q.G., B.H. (2)	Q.G., MT.H. (3)	Vol. (4)	Vol. less 20% (5)	Max. price (6)	Max. price less 11% (7)	Value (8)	Q.G., B.H. (9)	Q.G., MT.H. (10)	Vol. (11)	Vol. less 20% (12)	Estd. sale price (13)		Estd. sale price less 11% (14)	Value (15)
	in.	in.	cu. ft.	cu. ft.	d. per cu. ft.	d. per cu. ft.	£	in.	in.	cu. ft.	cu. ft.	d. per cu. ft.	d. per cu. ft.	£	£
20	4½	3·9	2,510	2,010	..	..	..	3·5	..	225	180	..	..	..	..
25	6½	5·0	3,540	2,840	..	..	..	5·1	4·1	435	350	2·0	1·8	2·6	..
30	8½	6·1	4,450	3,560	9·1	8·1	120	6·8	5·2	520	415	4·1	3·7	6·4	14·0
35	10	7·2	5,240	4,190	10·4	9·3	162	8·4	6·2	545	435	6·2	5·5	10·0	..
40	11½	8·1	5,930	4,750	11·3	10·1	200	9·8	7·1	545	435	8·2	7·3	13·2	25·2
45	13	9·0	6,570	5,260	12·1	10·8	237	11·2	7·9	520	415	9·1	8·1	14·0	..
50	14½	9·9	7,160	5,740	12·8	11·4	272	12·6	8·7	490	390	11·8	10·5	17·0	24·0

APPENDIX III

Calculation of the cost value of a normal forest of 100 acres of Norway Spruce, Quality II, worked on a 70 year rotation. (Picea abies Karst.)

(Similar calculations were made for Scots pine II, European larch II, and Douglas fir II.)

The calculation is based on the cost of 7 acres, 1 acre planted in each of the years 1883, 1893, 1903, 1913, 1923, 1933, and 1943, the costs being brought forward to 1948. The sum of the costs of these 7 acres is multiplied by $\frac{100}{7}$ to give the cost value of a forest of 100 acres. The method of calculation is an adaptation of the method explained on p. 148 of Schlich's *Manual of Forestry*, vol. iii, 5th edition, 1925.

The symbols are explained in Section IV. 2.

$S = \text{£}4$ and remains constant throughout the period.

$C = \text{£}54.7$

$e = \text{£}1.1$

$E = \frac{e}{.03} = \text{£}36.7$

$B = \text{£}11.7$

$T_{30} = \text{£}8.7$

$T_{40} = \text{£}8.2$

$T_{50} = \text{£}13.1$

$T_{60} = \text{£}15.7$

These are the costs and returns at 1948 wages. For previous years these figures are adjusted according to the wages index (see below).

Thus $C_{93} = \text{£}54.7 \times .15$

$T_{30(23)} = \text{£}2.7 \times .39$

$E_{93} = \text{£}36.7 \times 0.15$, and is regarded as remaining constant from 1888 to 1897.

Wage indices are:

1883-15	1923-39
1893-15	1933-35
1903-16	1943-63
1913-21	1948-100

Cost value of *growing stock* on acre P_{43} (i.e. planted in 1943)

$$\begin{aligned}
 &= (S + E_{43})(1.03^5 - 1) + C_{43} \times 1.03^5 \\
 &= (4 + 36.7 \times .63)(.159) + 54.7 \times .63 \times 1.159 \\
 &= 4.312 + 39.940 = 44.252
 \end{aligned}$$

$$\begin{aligned}
 \text{I acre, } P_{33} &= S(1.03^{15} - 1) + E_{33} \times 1.03^{10}(1.03^5 - 1) + E_{43}(1.03^{10} - 1) + C_{33} \times 1.03^{15} \\
 &= 4 \times 0.558 = 2.232 \\
 &\quad + 36.7 \times 0.35 \times 1.344 \times 0.159 + 2.742 \\
 &\quad + 36.7 \times 0.63 \times 0.344 + 7.946 \\
 &\quad + 54.7 \times 0.35 \times 1.558 + 29.828 = 42.748
 \end{aligned}$$

$$\begin{aligned}
 \text{I acre, } P_{23} &= S(1.03^{25} - 1) + E_{23} \times 1.03^{20}(1.03^5 - 1) + E_{33} \times 1.03^{10}(1.03^{10} - 1) \\
 &\quad + E_{43}(1.03^{10} - 1) + C_{23} \times 1.03^{25} + B_{43} \times 1.03^5 \\
 &= 4 \times 1.094 = 4.376 \\
 &\quad + 36.7 \times 0.39 \times 1.806 \times 0.159 + 4.106 \\
 &\quad + 36.7 \times 0.38 \times 1.344 \times 0.344 + 5.933 \\
 &\quad + 36.7 \times 0.63 \times 0.344 + 7.946 \\
 &\quad + 54.7 \times 0.39 \times 2.094 + 44.671 \\
 &\quad + 11.7 \times 0.63 \times 1.159 + 8.543 = 75.575
 \end{aligned}$$

$$\begin{aligned}
 1 \text{ acre, } P_{18} &= S(1.03^{35} - 1) + E_{13} \times 1.03^{30}(1.03^5 - 1) + E_{23} \times 1.03^{20}(1.03^{10} - 1) \\
 &\quad + E_{33} \times 1.03^{10}(1.03^{10} - 1) + E_{43}(1.03^{10} - 1) + C_{13} \times 1.03^{35} \\
 &\quad + B_{33} \times 1.03^{15} - T_{30(43)} \times 1.03^5 \\
 &= 4 \times 1.814 \qquad \qquad \qquad = 7.256 \\
 &\quad + 36.7 \times 0.21 \times 2.427 \times 0.159 \qquad \quad + 2.971 \\
 &\quad + 36.7 \times 0.39 \times 1.806 \times 0.344 \qquad \quad + 8.884 \\
 &\quad + 36.7 \times 0.35 \times 1.344 \times 0.344 \qquad \quad + 5.933 \\
 &\quad + 36.7 \times 0.63 \times 0.344 \qquad \qquad \quad + 7.946 \\
 &\quad + 54.7 \times 0.21 \times 2.814 \qquad \qquad \quad + 32.324 \\
 &\quad + 11.7 \times 0.35 \times 1.558 \qquad \qquad \quad + 6.380 \\
 &\quad - 2.7 \times 0.63 \times 1.159 \qquad \qquad \quad - 1.971 \\
 &\qquad \qquad \qquad \qquad \qquad \qquad \qquad \qquad = 69.723
 \end{aligned}$$

$$\begin{aligned}
 1 \text{ acre, } P_{03} &= S(1.03^{45} - 1) + E_{03} \times 1.03^{40}(1.03^5 - 1) + E_{13} \times 1.03^{30}(1.03^{10} - 1) \\
 &\quad + E_{23} \times 1.03^{20}(1.03^{10} - 1) + E_{33} \times 1.03^{10}(1.03^{10} - 1) \\
 &\quad + E_{43}(1.03^{10} - 1) + C_{03} \times 1.03^{45} + B_{23} \times 1.03^{25} - T_{30(33)} \times 1.03^{15} \\
 &\quad - T_{40(43)} \times 1.03^5 \\
 &= 4 \times 2.782 \qquad \qquad \qquad = 11.128 \\
 &\quad + 36.7 \times 0.16 \times 3.262 \times 0.159 \qquad \quad + 3.043 \\
 &\quad + 36.7 \times 0.21 \times 2.427 \times 0.344 \qquad \quad + 6.428 \\
 &\quad + 36.7 \times 0.39 \times 1.806 \times 0.344 \qquad \quad + 8.884 \\
 &\quad + 36.7 \times 0.35 \times 1.344 \times 0.344 \qquad \quad + 5.933 \\
 &\quad + 36.7 \times 0.63 \times 0.344 \qquad \qquad \quad + 7.946 \\
 &\quad + 54.7 \times 0.16 \times 3.782 \qquad \qquad \quad + 33.100 \\
 &\quad + 11.7 \times 0.39 \times 2.094 \qquad \qquad \quad + 9.559 \\
 &\quad - 2.7 \times 0.35 \times 1.558 \qquad \qquad \quad - 1.472 \\
 &\quad - 8.2 \times 0.63 \times 1.159 \qquad \qquad \quad - 5.987 \\
 &\qquad \qquad \qquad \qquad \qquad \qquad \qquad \qquad = 78.562
 \end{aligned}$$

$$\begin{aligned}
 1 \text{ acre, } P_{93} &= S(1.03^{55} - 1) + E_{93} \times 1.03^{50}(1.03^5 - 1) + E_{03} \times 1.03^{40}(1.03^{10} - 1) \\
 &\quad + E_{13} \times 1.03^{30}(1.03^{10} - 1) + E_{23} \times 1.03^{20}(1.03^{10} - 1) \\
 &\quad + E_{33} \times 1.03^{10}(1.03^{10} - 1) + E_{43}(1.03^{10} - 1) + C_{93} \times 1.03^{55} \\
 &\quad + B_{13} \times 1.03^{35} - T_{30(23)} \times 1.03^{25} - T_{40(33)} \times 1.03^{15} \\
 &\quad - T_{50(43)} \times 1.03^5 \\
 &= 4 \times 4.082 \qquad \qquad \qquad = 16.328 \\
 &\quad + 36.7 \times 0.15 \times 4.384 \times 0.159 \qquad \quad + 3.832 \\
 &\quad + 36.7 \times 0.16 \times 3.262 \times 0.344 \qquad \quad + 6.582 \\
 &\quad + 36.7 \times 0.21 \times 2.427 \times 0.344 \qquad \quad + 6.428 \\
 &\quad + 36.7 \times 0.39 \times 1.806 \times 0.344 \qquad \quad + 8.884 \\
 &\quad + 36.7 \times 0.35 \times 1.344 \times 0.344 \qquad \quad + 5.933 \\
 &\quad + 36.7 \times 0.63 \times 0.344 \qquad \qquad \quad + 7.946 \\
 &\quad + 54.7 \times 0.15 \times 5.082 \qquad \qquad \quad + 41.698 \\
 &\quad + 11.7 \times 0.21 \times 2.814 \qquad \qquad \quad + 6.914 \\
 &\quad - 2.7 \times 0.39 \times 2.094 \qquad \qquad \quad - 2.205 \\
 &\quad - 8.2 \times 0.35 \times 1.558 \qquad \qquad \quad - 4.471 \\
 &\quad - 13.1 \times 0.63 \times 1.159 \qquad \qquad \quad - 9.565 \\
 &\qquad \qquad \qquad \qquad \qquad \qquad \qquad \qquad = 88.304
 \end{aligned}$$

$$\begin{aligned}
 1 \text{ acre, } P_{83} &= S(1.03^{65} - 1) + E_{83} \times 1.03^{60}(1.03^5 - 1) + E_{93} \times 1.03^{50}(1.03^{10} - 1) \\
 &\quad + E_{03} \times 1.03^{40}(1.03^{10} - 1) + E_{13} \times 1.03^{30}(1.03^{10} - 1) \\
 &\quad + E_{23} \times 1.03^{20}(1.03^{10} - 1) + E_{33} \times 1.03^{10}(1.03^{10} - 1) \\
 &\quad + E_{43}(1.03^{10} - 1) + C_{83} \times 1.03^{65} + B_{03} \times 1.03^{45}
 \end{aligned}$$

$$\begin{aligned}
& -T_{30(13)} \times 1.03^{35} - T_{40(23)} \times 1.03^{25} - T_{50(33)} \times 1.03^{15} \\
& -T_{60(43)} \times 1.03^5 \\
= & 4 \times 5.830 & = 23.320 \\
& + 36.7 \times 0.15 \times 5.892 \times 0.159 & + 5.152 \\
& + 36.7 \times 0.15 \times 4.384 \times 0.344 & + 8.291 \\
& + 36.7 \times 0.16 \times 3.262 \times 0.344 & + 6.582 \\
& + 36.7 \times 0.21 \times 2.427 \times 0.344 & + 6.428 \\
& + 36.7 \times 0.39 \times 1.806 \times 0.344 & + 8.884 \\
& + 36.7 \times 0.35 \times 1.344 \times 0.344 & + 5.933 \\
& + 36.7 \times 0.63 \times 0.344 & + 7.946 \\
& + 54.7 \times 0.15 \times 6.830 & + 56.040 \\
& + 11.7 \times 0.16 \times 3.782 & + 7.080 \\
& - 2.7 \times 0.21 \times 2.814 & - 1.596 \\
& - 8.2 \times 0.39 \times 2.094 & - 6.697 \\
& - 13.1 \times 0.35 \times 1.558 & - 7.143 \\
& - 15.7 \times 0.63 \times 1.159 & - 11.464
\end{aligned}$$

= 108.756

The cost of 7 acres is the sum of these 7 costs = £507.920

The cost of 100 acres of growing stock = £7,256

Add 100 acres of land at £4 400

Total cost of normal forest = £7,656

APPENDIX IV

The Financial Rotation

It should not be assumed that the rotations of 100 years for Scots pine, 80 years for European larch, 70 years for Norway spruce, and 50 years for Douglas fir are the most profitable rotations. Is it possible to work out other rotations which would provide a better financial return?

The fundamental index of the profit from a plantation is the rate of compound interest which is earned on the capital invested in it. If the costs and returns of any plantation are known, the rate of compound interest which is earned can be worked out. But the result of this calculation has no general application if costs and returns are fluctuating at all violently. Any factor which raises the rate of interest, such as an especially low cost of formation or especially high prices at the time of felling, tends to shorten the financial rotation, and this is particularly the case when there has been a sharp fall in the value of money between the initiation and the marketing of the crop. But this would not be a sound reason for adopting short rotations in a normal forest, because the length of rotation must be based on a long term view. Consequently, the usual methods of computing financial rotations do not give results which are of much value in the present paper.

The figures in the following table show the *indicating per cents.*, worked out with Formula VII on page 159 of my *Economics of Forestry* (5), for second-quality plantations of four coniferous species.

The figures in this table are based on the value of a tree crop at the beginning and end of a 10-year period, the cost of maintenance of the crop during this period, and the value of the land. The figures afford some indication as to whether it is better to fell a wood at any particular age or to keep it for a further decade. The rate of interest shown is the average rate of simple interest earned, during the decade, on the sale value of the plantation and

the value of the land, after allowing for the cost of maintenance. It does not mean, however, that the owner can earn this rate of interest on his original investment, as the formula takes no account of the cost of formation of the plantation.

Indicating per cent.

<i>Interval (years)</i>	<i>Scots pine II %</i>	<i>European larch II %</i>	<i>Norway spruce II %</i>	<i>Douglas fir II %</i>
30-40	..	..	..	5.3
40-50	..	3.1	3.5	3.4
50-60	..	2.4	3.1	..
60-70	1.7	2.1	1.9	..
70-80	1.5	1.3	..	..
80-90	1.1	..	..	..
90-100	0.6	..	..	..

A further test may be applied by working out the net income from normal forests worked on shorter rotations. Column 10 of Table III shows the net incomes earned on 100 acres of normal forest of the four species with specified rotations. Corresponding figures have been calculated for shorter rotations, and the following results have been obtained.

Scots pine, II. Reducing the rotation from 100 to 60 years increases the annual *loss* on 100 acres from £48 to £63.

European larch, II. Reducing the rotation from 80 years to 60 years reduces the annual *profit* from £100 to £76.

Norway spruce, II. Reducing the rotation from 70 to 50 years converts a *profit* of £34 into a *loss* of £27.

Douglas fir, II. Reducing the rotation from 50 to 30 years converts a *profit* of £126 into a *loss* of £24.

These results do not suggest that, with present prices, the profit from forestry can be increased by adopting shorter rotations.

LITERATURE REFERENCES.

- (1) *Board of Trade Statutory Rules and Orders*, No. 2209 (1946). London: H.M.S.O.
- (2) Davey, R.: *Measurement of Trees*. Forest Press, Nutley, Sussex, 1942.
- (3) *Forestry Commission Yield Tables For Scots Pine and Other Conifers*. London: H.M.S.O., 1946.
- (4) Heske, Franz: *German Forestry*. Yale University Press, 1938.
- (5) Hiley, W. E.: *The Economics of Forestry*. Oxford University Press, 1930.
- (6) MacGregor, J. J.: 'Labour Costs in English Forestry since 1824.' *Forestry*, xx, 1946.
- (7) *Post-War Forest Policy: Report by H.M. Forestry Commissioners* (Cmd. 6447). London: H.M.S.O., 1943.
- (8) *Report from the Select Committee on Estimates*. London: H.M.S.O., 1929.
- (9) Schlich, Sir William: *Manual of Forestry*, vol. iii, 5th edition. Bradbury, Agnew & Co. Ltd., 10 Bouverie Street, London. 1925.

THE VARIATION OF DOUGLAS FIR IN ITS NATIVE HABITAT (*Pseudotsuga taxifolia* Brit. syn. *P. douglasii* Carr.)

By T. R. PEACE

(*Forestry Commission*)

INTRODUCTION.

DOUGLAS fir covers a very wide range of climate and condition in North America, extending as it does from British Columbia and south-west Alberta in the north, through all the Rocky Mountain states in the U.S.A. right down into Mexico. It was realized almost as soon as Douglas began to be used as a forest tree in Europe that attention would have to be paid to the source of the seed. It was also soon noticed that there was considerable variation between different trees, particularly between those growing in the two extremes of its habitat, namely, the coastal strip of British Columbia and the western parts of Oregon and Washington on the one hand, and the eastern Rocky Mountains in Colorado and neighbouring states on the other. So in Europe, and to a much lesser extent in America, experimental plantations were made in order to decide the best source of seed for European use, while quite independently systematic botanists of both countries have put forward their views on the proper botanical treatment of Douglas fir, often working on inadequate material. So far there has been practically no effort to correlate the systematic with the practical angle.

Additional importance attaches to investigations of this type on Douglas fir because of the two needle diseases, *Rhabdocline pseudotsugae* and *Phaeocryptopus gaumannii*, to which it is subject. These have done considerable damage in Europe, though they appear of little importance in America. *Rhabdocline*, at any rate, behaves very differently on Douglas fir of different origins.

In 1938 it was the author's good fortune to make an extended tour in the United States and Canada, in the course of which a reasonably representative sample of the Douglas fir area was visited. The opportunity was taken to collect specimens, to take photographs, and to make notes on Douglas fir seen in the areas visited; and in British Columbia a series of plots was selected, from most of which seed was subsequently collected. The approximate position of the places where specimens were collected and of the seed plots is shown on the maps. Before dealing with the information gathered in the course of this tour, however, it appears desirable to review briefly the work so far done on this aspect of Douglas fir.

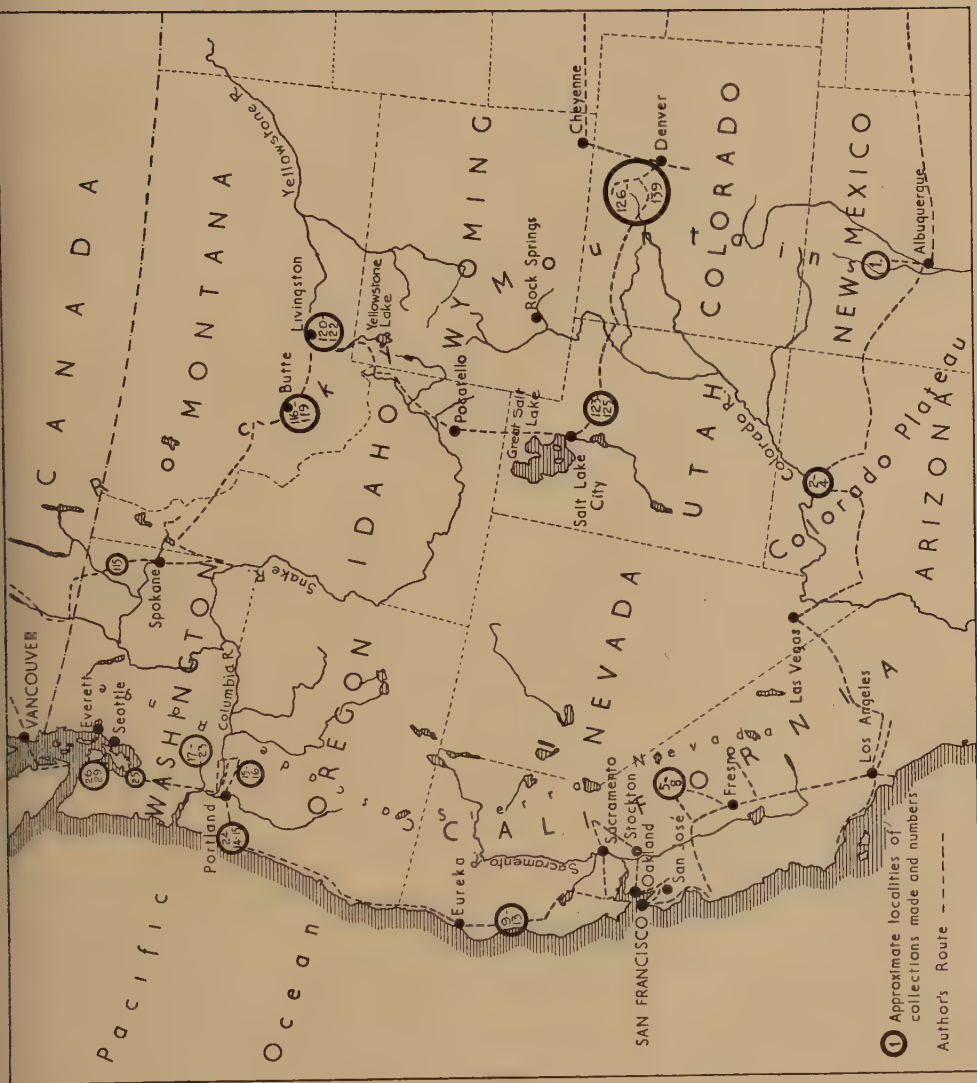
In the text-books Douglas fir has received varied treatment. Rehder (14) acknowledges only one species, *Pseudotsuga taxifolia*, although he mentions a large number of varieties, of which only one, *P. t. glauca*, the Rocky Mountain form, could possibly be distinguished on the description he gives. As compared

with *P. t. viridis*, the typical form of the coast, it is said to be a tree of slower growth and more compact habit, with ascending young branches, shorter leaves more or less bluish-green, and cones about 5 cm. long with spreading or finally reflexed bracts.

He also gives three varieties which he apparently regards as belonging to *P. t. viridis*, namely, *P. t. caesia*, leaves bluish-green, *P. t. fastigiata*, a pyramidal form with upright branches, and *P. t. pendula* with pendulous branches. Dallimore and Jackson (1) give two species, *P. douglasii* and *P. glauca*, the latter occurring in the central south Rocky Mountains. They distinguish *P. glauca* mainly by the shorter cones (2–3 inches as compared with 3–4 inches for *P. douglasii*) with their reflexed bracts, by the resinous winter buds, and by the needles which are usually more glaucous and of thicker texture. In the northern Rocky Mountains they distinguish the variety *P. d. caesia* which, they say, is intermediate between *P. douglasii* and *P. glauca*, and can be distinguished from the former by its glabrous or very slightly downy branches, only slightly fragrant greyish foliage and smaller cones, and from the latter by its pectinate foliage and erect cone scales. They also give a number of varieties of *P. douglasii*, mostly of only horticultural interest, but including var. *fastigiata*, var. *pendula*, and var. *taxifolia*. The first two appear to be the same as those quoted by Rehder, while var. *taxifolia* is said to have stouter branchlets, longer and narrower leaves, blunter cones, and shorter cone bracts than the typical form, and to occur in Oregon.

One of the first papers dealing exclusively with Douglas fir was written by Frothingham (5), who made only one species, *P. taxifolia*, and distinguished only two forms, the Coast and the Rocky Mountain. These two forms he separates on the grounds that, firstly, the foliage of the Coastal variety is dark green, whereas that of the Rocky Mountain one is often bluish, and secondly, the smaller cones of the latter variety have reflexed bracts. He gives a very useful map which shows the distribution of the tree and is divided into the following five regions:

- I. The North Coast Region, which includes the coastal-facing valleys of British Columbia, the western halves of Oregon and Washington, and the coastal strip of northern California, contains the Coastal form only.
- II. The Sierra Region, which includes the Sierra Mountains of northern California and the eastern slopes of the coast range in that State, is also part of the range of his Coastal form, but the trees do not reach such a large size as further north.
- III. The Northern Rocky Mountain Region, which includes the interior of British Columbia, south-west Alberta, north-east Washington, northern Idaho, and north-west Montana, is said to have both the Coast and Rocky Mountain forms of the Douglas fir, though Frothingham attaches the word 'probably' to the Coastal form, which suggests that he had not really paid close attention to this region.
- IV. In the Central Rocky Mountain Region, which includes central Washington, eastern Oregon, southern Idaho, southern Montana, Wyoming, northern Utah, and north-eastern Colorado, and in



① Approximate localities of collections made and numbers

Author's Route -----

V. the Southern Rocky Mountain Region, which includes southern Utah, southern Colorado, eastern Nevada, Arizona, New Mexico, and Mexico proper, only the Rocky Mountain form occurs.

Frothingham's regions have been described in detail, because, although his information on variation is limited, he does give a fairly complete picture of the distribution of Douglas fir as a whole.

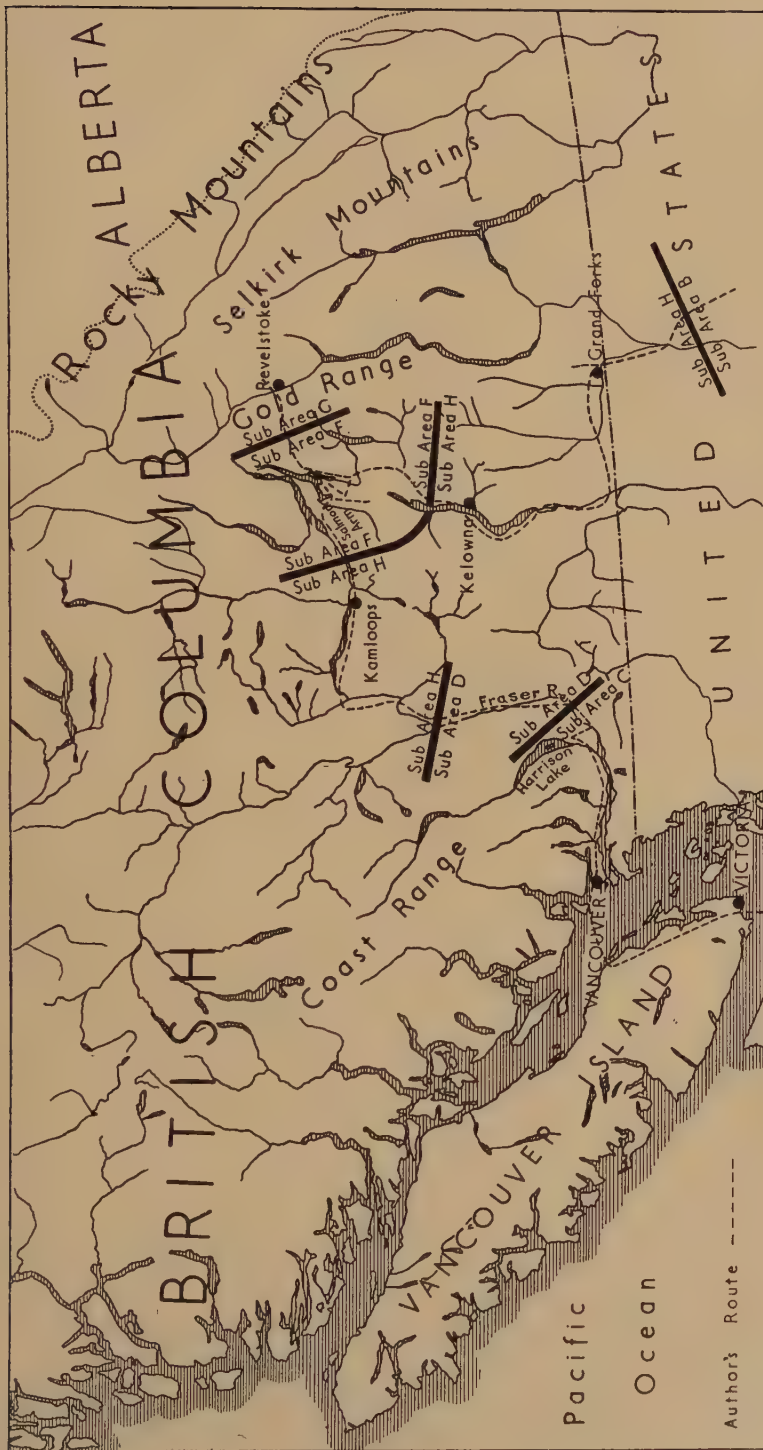
Henry and Flood (6) dealt with the tree in much more detail, separating *P. glauca* from *P. douglasii*, and giving var. *caesia* as a variety of the latter. Their descriptions are worth quoting in some detail. For *P. douglasii* they say, 'Leaves thin, flat beneath, lying either flat in one plane or with a V-shaped depression, not glaucous; branchlets pubescent without bloom, yellowish at first, grey in the second and third years; pulvini slightly elevated; buds with little or no resin; cones 3-4 in. long, bracts erect'. For var. *caesia* they have 'Leaves thicker than in *P. douglasii*, with a trace of glaucous bloom, intermediate in most respects between the Oregon (*P. douglasii*) and Colorado (*P. glauca*) species, pectinately arranged; branchlets glabrous, grey in the first, second and third years; pulvini elevated; buds resinous; cones 2½ in. long, with erect bracts'; and for *P. glauca*, 'Leaves thick, rounded beneath, not pectinate; branchlets variable in pubescence, glaucous or reddish brown, or without bloom, in which case they become grey in the second or third year; pulvini elevated; buds resinous; cones 2-3 in. long, with reflexed bracts; finally mentioning that *P. glauca* smells of turpentine and *P. douglasii* of pine-apples. They also give details regarding resin canals and idio-blasts, but in the author's opinion the use of internal characters for practical botanical distinctions is of very doubtful value in this instance.

Von Schwerin (16) makes only one species, *P. taxifolia*, but that he has subdivided to an extraordinary degree. First he made two sub-species *mucronata* and *glaucescens*, each of which he then divided into fourteen forms, most of them merely abnormal variations but several of more general interest. Among the latter, under *P. t. mucronata*, are *viridis*, the typical Coastal form; *viminalis*, with hanging secondary branchlets—the so-called 'feather' form; *brevibracteata*, the southern form of the 'green' Douglas fir, which has longer, darker needles, more compact growth, and cone bracts so short that they are scarcely visible; as well as *fastigiata* and *pendula*, mentioned above. *P. t. glaucescens* he divides into four sections:

- (a) Needles blue.
- (b) Needles merely slightly blue.
- (c) Needles with a waxy covering which makes them appear nearly white.
- (d) Needles green.

Under (a) he has form *glauca*, the typical Blue Colorado Douglas fir, under (b) *caesia*, and under (d) *laeta*, which he describes as a green-leaved variety with reflexed cone bracts.

In 1932 Flous and Gaussen (4) published a paper in which they separated Douglas fir into two species, *P. douglasii* and *P. glauca*, with *caesia* as a variety of the latter. But two years later, and again in 1936, Flous (2 and 3) published



additional papers in which, while retaining *P. douglasii* and *P. glauca*, she created seven new species. One, *P. vancouveriensis*, based on three specimens, was split off from *P. douglasii*, and the other six from *P. glauca*. *P. caesia* was raised to specific rank. Separate keys were given for determining the species, using external and internal characters. Twig pubescence, the arrangement and shape of the leaves, and various cone characters were all used. Although seven of her species were shown as occurring within the Rocky Mountain area and well within the range usually attributed to *P. glauca*, only two, *P. glauca* and *P. flabaultii*, had completely reflexed cone bracts; one, *P. macrolepis*, had the upper bracts reflexed, and the remaining four had normal bracts. This is of interest in view of the author's finding, reported later, that reflexed bracts are far from universal in the Rocky Mountain area. There is no reason at all to suppose that Flous was incorrect in the examination of her material, but she is open to criticism in that the amount of material she examined was hardly adequate for the creation of so many new species. The writer is convinced that if sufficient material were examined, anyone attempting to 'split' this genus would be forced either to increase the number of species beyond all reason or else admit that those species already created merge into one another through a series of almost indistinguishable intermediates.

It should be mentioned at this stage that there is a distinct species of *Pseudotsuga* in North America, *P. macrocarpa*, the so-called Big-cone spruce, which has a very limited distribution in the hills of southern California, quite separate from the range of the trees considered above. It is only of local importance in America, and of no importance in Great Britain, and therefore will not be considered further.

It will be noted that, in general, the papers considered above have something in common. They all distinguish a Green or Coastal type (*P. douglasii* or *P. taxifolia*), and a Rocky Mountain, Colorado, or Blue type (*P. glauca*), while most of them include a third Intermediate type (*caesia*), occurring in the interior of British Columbia, generally classified as a variety either of *P. douglasii* or *P. glauca*. There is also a measure of agreement in the characters used to separate these two species and one variety. *P. douglasii* is said to be distinguished by the fact that it has the longest cones with upright bracts, by the pectinate arrangement of the green needles, and by the pubescent branchlets. *P. glauca* is said to have much shorter cones with reflexed bracts, no regular arrangement of the usually glaucous or bluish needles, and branchlets variable in pubescence. *P. caesia* is said to have the smallest cones, but upright bracts, a pectinate arrangement of the often slightly glaucous needles, and nearly glabrous branchlets. There is also some agreement on the suggestion that *P. glauca* and *P. caesia* have more resinous buds and a steeper angle of branching than *P. douglasii*. Beyond this there is no general agreement. There is a tendency to separate other forms, either on growth habit, or on cone or foliage characters, particularly leaf colour, but with regard to these minor varieties there is not much agreement between the different authors.

Space does not permit adequate consideration of the many papers, chiefly in German publications, on provenance plots of Douglas fir planted in Europe. Munch (9 and 10) found that the only one of his seed origins which came from

the Coastal region grew better than all his others which were from much farther inland. He did not deal with the systematic side of the subject at all, although he did remark that one lot from New Mexico had a very columnar habit. Oppermann (12), dealing with Denmark, found that inland races grew better than those from the Coast. It is apparently mainly a matter of the superior hardiness of the inland origins, for on favourable sites the Coastal races grew faster. He described *P. caesia* as hardy and growing fairly well, and specifically mentioned one origin, from the California mountains, as being suitable for use in Denmark. Flous and Gausson (4) also stated that in France *P. glauca* was much less susceptible to frost than *P. douglasii*. Schenck (15) dealt with the matter largely from a climatic angle. Comparing the climates of North America with those of Germany, he concluded that the Coastal form from British Columbia should be suitable for growing in Germany, but not the Coastal form from farther south, which would probably not be hardy. Kanzow (7 and 8), as well as giving a summary of provenance experiments with Douglas fir in Germany and Denmark, also explored the climatic field more thoroughly, but arrived at roughly the same conclusions.

Munger and Morris (11) gave a very full report on provenance plantings made with Douglas fir of thirteen seed origins on four different sites, but all the seed-collecting areas and planting sites were within the range of the Coastal form of the tree in Oregon and Washington. No botanical data were given, but in rate of growth and in date of flushing there was a wide variation between trees of different seed origins. All these provenance experiments do most certainly indicate that one is dealing with a very variable tree.

In Great Britain the practising forester has usually distinguished three forms of Douglas fir, the Green or Coastal, the Blue or Colorado, and the Intermediate or Fraser River, corresponding approximately to the normally accepted *P. douglasii*, *P. glauca*, and var. *caesia*. The writer considers that the colour names should be dropped, as should the name 'Fraser River', which is a misnomer, since the bulk of the area generally assigned to var. *caesia* is not in the Fraser River valley at all. Therefore, for purposes of discussion, the terms Coastal, Intermediate, and Colorado Douglas fir will be used.

In Great Britain the Colorado form grows very slowly and is almost invariably severely attacked by *Rhabdocline pseudotsugae*, so that it is of little value. As the greater part of the British plantations appear to have originated from seed collected in the Coastal area, they are free from *Rhabdocline*, though affected by the aphid *Adelges cooleyii*, and, in the west, by the fungus *Phaeocryptopus gaumannii*. However, knowledge of the extent to which the tree is really damaged by the last two named is so far incomplete. The Intermediate form, raised mostly from seed collected near Salmon Arm in British Columbia, has been quite widely planted in Great Britain and is generally growing well, though in the main rather slower than the Coastal form. It is susceptible to *Rhabdocline*, though it is not affected as seriously as the Colorado Douglas fir, nor to such an extent as to threaten its use in the country. It is also attacked by *Phaeocryptopus* and *Adelges*. Nothing can be said about the relative susceptibilities of the three forms to *Phaeocryptopus*, since the general behaviour of this fungus is still obscure.

THE DISTRIBUTION OF THE MATERIAL COLLECTED.

In considering the material collected and the observations made, some form of regional grouping is obviously desirable. Inadequate collections in many of the regions that were actually visited and the fact that many parts of the range of Douglas fir were not touched, make such a division difficult, but the scheme adopted is set out in Table I.

TABLE I. *Collection Areas*

<i>Main area</i>	<i>Sub-area</i>	<i>Collection nos.</i>	<i>Seed plot nos.</i>	<i>Total collections and plots</i>
I. Rocky Mountain	A. Jamez Mts. and Grand Canyon	1-4	..	4
	B. Montana, Utah, and Colorado	17-21, 116-39	..	29
II. Coast	C. Coast proper	9-16, 22-45	1-3	35
	D. Fraser River Canyon	46-62	4-6	20
	E. Californian Sierra	5-8	..	4
III. Interior B.C.	F. Salmon Arm and Taft	77-84, 93-109	8, 9, 12-14, Spec. Trees	
			13 and 14	32
	G. Revelstoke	85-92	10-11	10
	H. Kamloops and Grand Forks	63-76, 110-15	7	21
				Total 155

It appears desirable also to give some idea of the amount of material examined, which varied for different characters. Most leaf and twig characters were determined from the material collected, and the number of collections made in each area is shown in Table I. Considerable quantities of cone material were received from those seed plots which were actually used for collection, that is, numbers 1, 3, 6, and 8-14, and also from Special Tree No. 14, which, together with No. 13, was selected before the author's visit as a typical tree of the intermediate type; but, on the other hand, cones were not available from all the trees from which leaf and twig material was collected. Data on leaf colour, as well as additional information on certain other characters, were based on notes, which unfortunately were not made for a few of the earlier collections. The angle of the crown and the angle of branching were measured on the fifty-seven photographs that were taken. Some of the photographs were of trees from which specimens were collected and others of trees from which no material was available. They were rather unequally divided between the main areas, there being thirty-four for Area II and only eleven and twelve for Areas I and III respectively. Every sub-area was represented by some photographs, but G and H had only two each.

Douglas fir covers a very wide climatic range, and there are considerable differences in rainfall, temperature, and length of growing season between the

regions listed in Table I. A brief summary of the climatic data available is given in Table II.

TABLE II. *Climate of the collection areas*

Sub-area	Mean annual rainfall	Growing season (days)	Extreme shade temperatures over a period of years	
			Max.	Min.
A. Jamez Mts., and Grand Canyon .	15-20 in.	140-200	104° F.	-22° F.
B. Montana, Utah, and Colorado .	14-18 in.	85-160	106° F.	-52° F.
C. Coast proper	20-52 in.	140-230	104° F.	-29° F.
D. Fraser River Canyon	50-65 in.	..	100° F.	-10° F.
E. Californian Sierra	34-36 in.	135-210	114° F.	- 6° F.
F. Salmon Arm and Taft	18-28 in.	..	100° F.	-25° F.
G. Revelstoke	30-42 in.	..	100° F.	-25° F.
H. Kamloops and Grand Forks . .	10-15 in.	..	100° F.	-40° F.

Much more detailed figures would be necessary if a proper comparison were to be made between the different areas. It will be noticed how very variable is the climate of the interior of British Columbia (D, F, G, and H), including as it does the driest and wettest of the areas studied. In this connexion it must be pointed out that the Coast Area is really wetter than the figures 20-52 inches suggest. Most of the Douglas fir sites probably have rainfalls of over 30 inches. In any case, of course, rainfall and temperature figures considered on such a broad basis are bound to be rather deceptive. Particularly in the hotter and more arid parts of its range, Douglas fir is confined to certain sites. The farther south one goes, for instance, the higher is the elevation at which the tree occurs, and the more apt it is to be confined to cool north-facing slopes. To get a clear picture of the regional climate as it really affects Douglas fir would require special readings taken in a large number of selected sites actually in Douglas fir stands.

It is unfortunate that no figures for the length of the growing season are available for British Columbia. Since in any one locality the tree grows at widely differing altitudes, wide variations within a comparatively small area may be expected, but on the average the tree has a longer growing season near the coast than inland, and this is undoubtedly one factor contributing to its superior growth in the former area. Maximum temperatures show surprisingly little variation and it is improbable that they have much influence on the tree. High temperatures are reached more frequently in the interior than near the coast. Again, the variation in minimum temperatures is surprisingly small, but if the Coast Area had been confined to a fairly narrow coastal strip in Oregon and Washington, so that none of the inland regions of these two states was included, a much higher minimum would have resulted. That part of the coast region within the influence of the sea has a much more equitable climate than the rest of the range of Douglas fir.

PROVENANCE PLANTINGS IN GREAT BRITAIN.

There appear to be very few provenance plantings of Douglas fir in this country,

and most of the existing ones suffer from lack of exact data on the localities from which the seed was collected. It is quite common to find Coastal and Colorado Douglas fir planted side by side although, again, it is seldom possible to ascertain from what part of those large regions the seed came. Where such comparisons can be made, the Coastal is invariably of far faster growth, and the Colorado alone attacked by *Rhabdocline pseudotsugae*. Usually a few individuals in the Colorado stands escape infection, and the fact that these, while greatly superior to their infected brethren, are still smaller than the Coastal type, does appear to support the idea that the inland races are inherently of slower growth.

A provenance planting has been made with plants raised from seed collected from the numbered plots selected during the author's visit, but alterations in the flow of water through the area, due to mining operations, have spoilt some of the plots, and the whole experiment, which was planted in the years 1942 and 1943, is still too young for major results. Seven additional seed origins were also included, four from Vancouver Island in the Coastal region, one from Salmon Arm (Sub-area F), one from Prince George, which is near the northern limit of Douglas fir in the interior of British Columbia and outside the areas visited by the author, and one from near Denver in Colorado. One of the Vancouver Island lots, together with Plot 1 (Harrison River, which also lies in the Coastal region), have grown best. Next best are the two Salmon Arm origins (including Plot 14) and Plot 10 from Revelstoke. Then, though not much better than the remainder, come Plot 9 from Sorrento, which is in the same sub-area as the Salmon Arm lots, and two more of the Vancouver Island origins. Of the remainder, the worst so far is Plot 6 from Lytton, which lies at the dry end of the Fraser River canyon and has a much lower rainfall than most of the other parts of the coastal zone, and in fact might have been included with almost equal justification in the neighbouring dry Kamloops area.

LEAF DISEASES OF DOUGLAS FIR IN AMERICA.

The information that was collected on the occurrence of fungi on Douglas fir in America is too meagre to be worthy of detailed consideration. At the time of the author's visit he was not familiar with *Phaeocryptopus* nor aware of its growing importance in Europe, so that he made no effort to find it. The inconspicuous fructifications do not call attention to its presence, although it is known to occur in north-west America. *Rhabdocline*, on the other hand, is much more easily observed, and was already familiar to the author, who kept a careful look-out for it. It was found in Oregon on a few trees definitely of Coastal origin, but the attack was only slight. The only severe case seen in the Coastal area was on trees of an inland race planted in an experimental plot in Oregon. *Rhabdocline* was also found on a few trees in the interior of British Columbia. It was not found in the Coastal area of British Columbia, nor in the inland states of the U.S.A., though, of course, this is no evidence that it does not occur there. It seems possible that the inland climate is too hot or too dry for the development of this fungus, but that the coastal climate, and to a smaller extent the less extreme climate of inland British Columbia, is suitable for it. Thus the highly susceptible Colorado Douglas

may be attacked only if planted outside its range, in a moister, cooler climate. It is interesting to note that the Coastal form was found even mildly attacked, since in Great Britain there are only one or two doubtful records of the fungus on it. The fungus itself seems to be rather variable in north-west America; possibly only one form was introduced into Great Britain, where it scarcely varies at all.

EVALUATION OF BOTANICAL CHARACTERS.

There are various ways in which the botanical characters can be compared. If a measurement, such as needle length, is under consideration, an average value can be calculated for each region and comparisons made between these values. If the character under consideration cannot be measured, for instance, in the case of leaf-scars, which were classified as 'prominent' (3), 'moderately prominent' (2), and 'flat' (1), an evaluation can be made by giving an artificial value to each character (as indicated in brackets), adding up these values for each region and dividing by the number of specimens classified. Then comparison can be made between different regions; those showing higher values will be those, on the average, with more prominent leaf-scars. But comparisons made in this way are apt to be deceiving. There may be big differences between the average values but so much overlapping between individuals that the character is of no value for diagnostic purposes. For this reason, in considering the individual characters below, the author has also taken into account the range of variation in each case, and indicated where, in his opinion, the overlap prevents a particular character from being used for diagnostic purposes.

The various characters examined are dealt with in some detail below. It will be noted that internal characters have not been included. If examination of external characters had brought to light any well-defined species or varieties, it would have been of interest to discover whether the differences were strengthened or weakened by the evidence of internal characters; but since the examination of external characters convinced the author that he was dealing with a complete range of variations, differences in internal characters would not have been likely to make matters any clearer.

Leaf characters.

Leaf colour was studied on both the current year's and older needles. Green and blue-green trees occurred commonly in all regions, with a slight but definite tendency for the former to predominate in the coastal area, and for the latter to predominate in the Rocky Mountains and the interior of British Columbia. Really blue trees, in the sense that *Cedrus atlantica glauca* or good types of *Picea pungens* are blue, were comparatively rare. Although they were seen in all the three major areas studied, collections from such trees were made only in Sub-areas B, C, and D. Blue trees were found to occur either as scattered individuals or, more rarely, in patches. Actually, the most striking stand of blue trees seen was at Yale, at the lower end of the Fraser River canyon, which, in this paper, is included in the Coastal area. Nothing so finely coloured was seen in the Rocky Mountains, and it is considered that the use of the name 'Blue Douglas fir' for the

Colorado variety is a complete misnomer. It will be noted that really blue trees were seen in the coast area proper; and recently the author has seen at Doune, near Aviemore in Scotland, a very blue Douglas fir which, from its size, rate of growth, and general health, must be of Coastal origin.

The length of needles varied from 1.5 to 3.5 cm. and was probably considerably affected by growing conditions, particularly moisture, since the two lowest average lengths, 1.8 cm. and 2.0 cm. respectively, were given by Sub-areas H and B, both dry areas. In the main areas the Coastal had an average of 2.4 cm., as compared with 2.0 cm. for the Rocky Mountain, and 2.1 cm. for the Interior of British Columbia. Even without considering the effect of rainfall, differences are not consistent enough for needle length to be regarded as a distinguishing character. The thickness of the needles, a character used by Henry and Flood (6), was not examined in detail, but a tendency to thicker needles was noticeable in the Rocky Mountain Area.

Sharpness or bluntness of the tips of needles was not confined to any one sub-area, though, on the average, there was quite a distinct tendency for the Interior of British Columbia to have a higher proportion of sharp needles than the other two main areas.

In agreement with the authorities already quoted, it was found that the Colorado Douglas fir (Area I) did not yield any specimens with the needles really pectinately arranged (i.e. in a V along the shoot). But while the V was absent here, it was very far from being generally present in the other two main areas.

There were no significant differences in the density of the foliage on the twigs. The more luxuriant appearance of some of the types commonly occurring in the coastal area was due rather to the number of twigs than to the actual density of the foliage on them. In this connexion it is interesting to see how little difference there is in the general density of the two trees shown in Figs. 4 and 7, and how much difference between the various trees in Fig. 3.

In areas (roughly Areas II and III) which were visited at the right time of year to observe dates of flushing, there were nearly always wide differences between neighbouring trees (Fig. 3), as indeed there are to be found in any Douglas fir plantation in Great Britain. Differences in altitude and in the time of year at which the trees were seen (the first Douglas fir specimen was collected in New Mexico on 28 April, and the last in Colorado on 26 June) prevented any comparison between trees in different areas.

Twig characters.

Completely glabrous twigs were rare but were found in Sub-areas B, C, and H. Extremely pubescent twigs were found in all the sub-areas except D and E. It will be seen, therefore, that pubescence is not valid on a regional basis, but on the average there was a tendency for the Rocky Mountain Area to show more pubescence than the other two main areas.

Variation in prominence of leaf-scars was found in all areas, but, taking the main areas, the Coastal had on the average the least prominent, and the Rocky Mountain the most prominent leaf scars. (The buds were not dealt with, as

owing to delay the specimens were too dry by the time they were examined to show amounts of resin clearly.)

Cone characters.

Cone lengths ranged from 3·4 to 8·4 cm. (1·3 to 3·3 in.). The Rocky Mountain Area had decidedly the shortest cones, with an average length of 5·2 cm. (2·0 in.). There would have been no appreciable difference in length between the Coastal area and the Interior of British Columbia if it had not been for the great length (average 7·8 cm., i.e. 3·0 in.) of the cones from the Fraser River canyon. This brought the average for Area II up to 7·0 cm. (2·7 in.), compared with 6·5 cm. (2·5 in.) for Area III. It had been intended to include the relative lengths of cone bracts and scales, but unfortunately the work was carried out by two persons, whose estimations of relative lengths did not agree. In the stress of war the cone material was lost before this discrepancy could be remedied. For what they are worth, the figures indicate that there was no significant difference between the main areas in this factor.

In the past the reflex cone bract has been regarded as one of the best characters for distinguishing Colorado Douglas fir from the Coastal or the Intermediate type. This character has been constant in all the lots of supposed Colorado Douglas fir examined in Great Britain, and the author has never found here a tree seemingly of the Coastal type that had reflexed bracts. But in America the matter was not so straightforward. One tree bearing some cones with reflexed bracts was found in the Olympic Mountains in the Coastal region, while several in the interior of British Columbia had some or all of the cones with reflexed bracts. Even more surprising still was the fact that several trees from the Rocky Mountain Area had cones without reflexed bracts. Thus the character that had appeared the most definite was found not to be entirely reliable.

Characters of form.

The angle of branching, measured by protractor from photographs, proved to be a character of no significance, though it might possibly have had some significance if more photographs of really young trees had been available for measurement. Fig. 3, taken in Oregon, shows one tree with very steep-angled branching, though this feature has been given as a character for the Colorado and Intermediate types. Measurements of the angle of the crown do appear to indicate that trees in the interior of British Columbia have narrower crowns than those from the other two areas, but this is by no means a character of diagnostic value.

One character of great importance to the forester, that of rate of growth, was not studied. Undoubtedly it is an inherent character, and in America as in Great Britain trees growing side by side under exactly similar conditions may show widely divergent rates of growth. But to have compared the rates of growth in different areas would have involved study of the effect that soil and climate have on this factor, and this was obviously outside the scope of the present investigation. In general, however, growth is much slower in the interior than in the

Coastal region, and the size reached by mature trees is much smaller. Figures from provenance experiments on the continent of Europe suggest that, while this difference is to some extent controlled by climate, there is an inherent basic difference which is quite considerable.

INTERMEDIATE DOUGLAS FIR IN GREAT BRITAIN.

In 1937 a short investigation was made into plantations of Intermediate, or so-called Fraser River, Douglas fir by Mr. A. G. Hoyle of Oxford and the writer. The conclusions at which they arrived are quoted below:

'Identification of Fraser River Douglas fir.

'The characters of this form are (as far as can be discovered from the material seen):

1. Habit stiff and upright, with straight leader, rarely, if ever, sinuous. Upper branches diverging at an angle of 45° or less, and curving upwards. Lower branches either curving upwards or spreading obliquely outwards, not pendulous at the ends. Confusion can occur, in this connection, between the Fraser River form and the vigorous forms of "Green", but in the latter the foliage is much denser and darker in colour.
2. Foliage rather sparse as compared with both "Green" and "Blue". Needles distinctly yellowish- to greyish-green, broader and thicker than in "Green" Douglas. Needles on upper side of shoot all pointing stiffly forward as well as upward and outward, leaving a clear but very narrow V-shaped furrow between. Again this character is shown to some extent by the vigorous forms of "Green", but "Blue" Douglas has the upper side of the shoot covered by the uppermost needles pointing forward over it.
3. Cones smaller than in either "Green" or "Blue", with the 3-pointed bract-scales well exerted beyond the cone-scales as in "Blue", but not reflexed as they are in "Blue".
4. Vegetative buds, probably always with more numerous small basal scales than in either of the other two forms, and more resinous.

'Although the typical form (as understood from the plantations seen) is fairly easily recognised in the field, there are several forms of it, some approaching more nearly to the "Blue" form, others to the "Green". It therefore becomes a matter of some difficulty to identify individual trees in a mixed plantation, while dried specimens are still more difficult, especially when no cones are available. The line of division between adjacent blocks of Fraser River and "Green" is clear enough from a distance, but when one gets among them it is sometimes impossible to say for certain whether an individual tree lies on one side of the line or the other.'

The stands of Intermediate examined were mostly raised from seed collected in the neighbourhood of Shuswap Lake and, despite the remarks quoted above, do appear to be of a much more uniform type than occurs naturally there or anywhere else in the interior of British Columbia. The author's observations and collections in America covered 2 and 3 above and have resulted in rather different

conclusions. Certainly the sinuous leader, which is probably only a sign of over-rapid growth, is commoner near the coast than inland and, perhaps, commoner in Great Britain than in America; and the pendulous habit is a coastal characteristic, though it does occur inland. Vegetative buds were not considered in this investigation, admittedly an unfortunate omission, nor was smell, since the author's sense of smell and memory for scents are both poorly developed. Certainly, to the author, the Intermediate type was not so clearly distinguishable in its native haunts as it appeared to be in plantations in Great Britain. Stands of Intermediate Douglas fir in Great Britain usually show a more uniform but rather slower rate of growth than the Coastal type, and exhibit a certain degree of susceptibility to *Rhabdocline pseudotsugae*. In a few forests Intermediate Douglas fir has definitely done better than the Coastal. If this were proved to be due to site factors, further investigation of the variations of the tree in the interior of British Columbia, and the selection of outstanding types for propagation, would be most desirable.

CONCLUSION.

It will be seen, therefore, that from the characters examined it would not be possible, with any certainty, to distinguish Douglas fir coming from one region from Douglas fir coming from another. Obviously, those anxious to split Douglas fir into many species or varieties could claim that there was no reason to assume that the range of the different species or varieties would not overlap, and that dealing with the question on a regional basis, as this paper does, was not a reasonable approach. Certainly, using all the more important characters, one could refer each tree examined to a new species or variety if it differed in any one character from those already examined; and when two different types occurred on the same site one could say that their ranges overlapped. In the author's opinion, provided a sufficient number of trees were examined, nearly every combination of characters would be found, if not on every site, at least in every climatic region, though some characters, for instance the reflexed cone scales, might well predominate in certain regions and be very scarce in others. If this is so, it is probably waste of time to go farther than to indicate that there are two outstanding types; the Colorado type, having small cones with reflexed bracts, short and possibly thick needles, which are never pectinately arranged and have a tendency to be bluish in colour; and the Coastal type, having long cones with upright bracts, long and possibly thin needles, which are often pectinately arranged and have a tendency to be green; and that between these two types, all sorts of variations occur, both on the coast and in the Rocky Mountains, but particularly in the interior of British Columbia.

From the practical angle of seed collection, this means that there is little hope of collecting a pure race. On the other hand, there are ample opportunities of collecting from local stands consisting mainly of a particular type, or from selected individuals of desirable character. The only hope of raising a pure strain of a good type would appear to lie in vegetative propagation in the first instance, and the planting of a 'seed orchard' with the plants thus raised. Particularly

attractive as material for such work is the form characterized by its rigid habit, dark green needle colour, fast growth, and late flushing. This form, which occurs most frequently near the Coast in America, is met with in nearly every plantation of Coastal Douglas fir in Great Britain.

Thanks are due to the Forestry Commission for assistance which made the tour of the Douglas fir region possible, and for permission to publish this paper. In the United States and Canada, willing help was received from everyone concerned, and the author can only single out the Forest Service of British Columbia for special mention. He would also like to express his gratitude to Miss K. M. Turner, who has assisted in summarizing the data, and corrected the manuscript.

SUMMARY.

In 1938 the author made a tour of part of the range of Douglas fir in North America and collected herbarium material.

A brief review is given of the literature on the botanical treatment of this tree, and on European provenance experiments with it. There is fairly general agreement in making two species, *P. taxifolia* or *P. douglasii* of the Coastal regions, and *P. glauca* of the Rocky Mountains, with a variety, *caesia*, occurring in the interior of British Columbia. There is some measure of agreement on the characters distinguishing these two species and one variety.

The author's observations and collections throw considerable doubt on the validity of these distinctions, since nearly every character that was used breaks down to some extent in practice. One is faced, therefore, with two alternatives: either to split Douglas fir into a very large number of species or varieties, whose ranges would be completely overlapping, or to admit that the tree is a complex of variables between two extreme types approximating to the former conceptions of *P. douglasii* and *P. glauca*, and to make no attempt at further botanical distinction. The author is entirely in favour of the second alternative.

ADDENDUM.

Since writing the above paper the author has had his attention called to 'La Sperimentazione di Specie Forestali Esotiche in Italia' by Professor A. Pavari and Professor A. de Philippis (*Annali della Sperimentazione Agraria*, 1941). In this book the writers give a comprehensive review of the literature on Douglas fir, with particular reference to provenance experiments.

On the basis of trees growing in Italy they distinguish two forms of the Coastal Douglas fir.

One has rough, heavily fissured, dark-coloured bark, spreading branches, very abundant foliage, needles shining and of soft texture, inserted almost at right angles to the branchlet. This form they regard as the typical Green Douglas fir.

The other has a less tapering trunk, with smoother, paler bark. The branches in the upper part of the trunk are sub-erect, the foliage is less dense, and the somewhat leathery leaves are inserted more or less obliquely to the branchlet, pointing forward; the cone is less elongated than in the typical form. They also state that although it is not entirely identical with *P. vancouveriensis* of Flous (2)



FIG. 1. Douglas fir in Yosemite National Park in the Californian Sierra Region. Trees are, on the whole, of the Coastal type, but with rather short needles, not pectinately arranged.



FIG. 2. Douglas fir at Willetts, in the Coastal belt of California. Note the fairly wide crowns and slightly drooping branches, a type very common in the Coastal area.



FIG. 3. Young Douglas fir at Rose Lodge, Otis, Oregon. Note the difference in date of flushing between *A* and *B*, the much denser foliage of *C*, and the steep-angled branching of *D*. This photograph illustrates very clearly the extreme variability of the species.



FIG. 4. Young Douglas fir at Cassidy, Vancouver Island. This is a tree of a type common in the Coastal area, with rather dense, bluish, non-pectinate foliage.



FIG. 5. Douglas fir at Seed Site 7, near Kamloops, British Columbia. This tree has a narrow crown and somewhat steep-angled branching, but very green foliage. This is a dry region, and the Douglas fir forms very open stands mixed with *Pinus ponderosa*.



FIG. 6. Tree No. 14 Salmon Arm, British Columbia. This rather older tree, which was selected by the forest authorities as being typical of the Intermediate type, has no longer any tendency to upright branching.



FIG. 7. Young Douglas fir between Raymond and Ward, Colorado. This tree had green and quite dense foliage, and was not acutely branched, but it had reflexed cone bracts.



FIG. 8. Douglas fir, growing with *Pinus ponderosa*, at La Cuvea, Jemez Mountains, New Mexico. A narrow-crowned type with reflexed cone bracts.

it is certainly very near to it. They are inclined to regard the typical form as the southern and the second form as the northern type of Coastal Douglas fir. The writer has seen trees of the two forms in Professor Pavari's arboretum at Vallombrosa, near Florence, and would agree that there the two varieties are quite distinct. Nevertheless, the view is taken that we are dealing here merely with two chance selections from the wide range of Douglas fir, and that they cannot be given the wide significance that the authors attribute to them.

LITERATURE REFERENCES.

- (1) Dallimore and Jackson: *A Handbook of the Coniferae*. Ed. Arnold & Co., London, 2nd edn., 1931.
- (2) Flous, F.: 'Diagnoses d'espèces et variétés nouvelles de *Pseudotsuga* américains.' *Travaux Lab. Forestier, Toulouse*, tome i, vol. ii, art. vi, 1934.
- (3) —: 'Revision du Genre *Pseudotsuga*.' *Ibid.*, tome ii, vol. iv, art. ii, 1935.
- (4) Flous and Gaussen: 'Les *Pseudotsugas* et leur résistance au froid en France.' *Ibid.*, tome i, vol. i, art. xx, 1932.
- (5) Frothingham, E. H.: *Douglas fir; A Study of the Pacific Coast and Rocky Mountain Forms*. U.S. Dept. Agric. Forest Service Circular 150, 1909.
- (6) Henry and Flood: 'The Douglas Firs.' *Proc. Royal Irish Academy*, xxxv. 67-92, 1919-20.
- (7) Kanzow, H.: 'Auswertung einiger Provenienzversuche mit der Douglasie.' *Mitteilungen der Deutschen Dendrologischen Gesellschaft*, xlviii. 235-54, 1936.
- (8) —: 'Die Douglasie.' *Zeitschrift für Forst- und Jagdwesen*, lxix. 65-93, 113-39, 241-71, 1937.
- (9) Munch, E.: 'Anbauversuch mit Douglasfichten verschiedener Herkunft und andern Nadelholzarten.' *Mitt. der Deutschen Dendrol. Gesellschaft*, pp. 61-79, 1923.
- (10) —: 'Klimarassen der Douglasie.' *Centralbl. für das ges. Forstwesen*, pp. 254-60, 1928.
- (11) Munger and Morris: *Growth of Douglas Fir Trees of known Seed Source*. U.S. Dept. Agric. Tech. Bull., No. 537, 1936.
- (12) Oppermann, A.: 'Racer af Douglasie og Sitkagran.' *Det Forstlige Forsøgsvaesen Danmark*, x, no. 90, pp. 85-178, 1929.
- (13) Pavari, A., and de Philippis, A.: 'La Sperimentazione di Specie Forestali Esotiche in Italia.' *Annali della Sperimentazione Agraria*, 1941.
- (14) Rehder, A.: *Manual of Cultivated Trees and Shrubs Hardy in North America*. The Macmillan Co., New York (2nd edn.), 1947.
- (15) Schenck, C. A.: 'Die Douglasfichte in British Columbia.' *Mitt. der Deutschen Dendrol. Gesellschaft*, pp. 66-75, 1924.
- (16) von Schwerin, F. G.: 'Die Douglasfichte.' *Ibid.*, pp. 53-67, 1922.

FROST DAMAGE AND RECOVERY IN SITKA SPRUCE IN THE NEW FOREST, HAMPSHIRE

(*Picea sitchensis* Carr.)

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SITE.

IN the south-east corner of Knightwood Inclosure, in the New Forest, is a small shallow valley at an elevation of 100 feet with a south aspect. The site is well sheltered. At the time concerned there was an established plantation across the mouth of the valley containing oak and pine some 40 to 50 feet in height which would greatly impede drainage of cold air.

HISTORY.

The valley was well drained and planted with Sitka spruce (*Picea sitchensis* Carr.) in 1921. A series of late spring frosts in 1927, 1928, and 1929 played havoc with the plantation, killing the leading shoots of the more vigorous Sitka and completely killing many of the smaller trees.

The plantation was left without further treatment in order to see what recovery the Sitka would make. Natural Scots pine (*Pinus sylvestris* L.) had already come in from the adjacent older belt and it was appreciated that if the spruce were to fail completely, there would still be a full crop of pine.

CONDITION IN 1947.

In 1947 an endeavour was made to assess the results. Over an area of about 2 square chains around the confluence of the drains was a pure stand of Sitka spruce. The dominant trees were of good form and over 40 feet in height, but some had a kink in the stem. Moreover, an adjacent intermediate zone carried a mixed crop of Scots pine and Sitka where many of the latter, not more than 25 feet in height, showed distinct kinks—the main axis continuing vertically after a lateral displacement of 3 to 5 inches—at heights from 2 to 5 feet above ground-level. In this intermediate zone also were many Sitka spruces which had recovered from the frost damage but had been subsequently suppressed by the more vigorous natural pines. Finally, the outer zone was of pure Scots pine amongst which the remains of the dead Sitka spruce could still be found.

There was thus displayed an almost unbroken profile of the development of Sitka from 1929 to the present time; and the nature of the frost kinks in the spruce stems is considered below, with photographs from a dominant tree.

DESCRIPTION OF SELECTED TIMBER SPECIMENS.

Fig. 2 of Plate III shows a longitudinal section 4 feet in length through a kink in a dominant spruce, 40 feet in height, the kink occurring about 7 feet above



FIG. 1

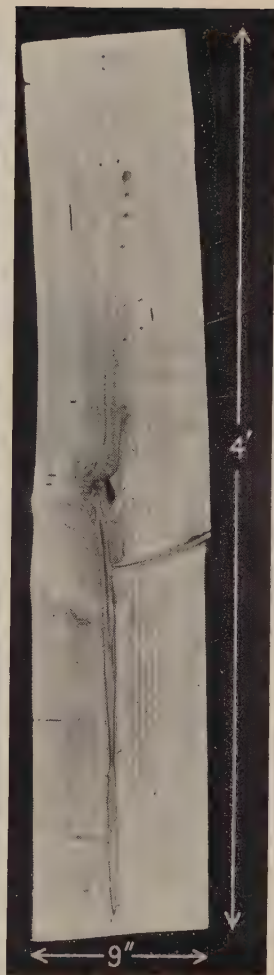


FIG. 2

Sitka spruce (*Picea sitchensis* Carr.) from New Forest, Hampshire. Planted 1921. Leader killed by frost when about 7 feet high. Good recovery by a side branch which took the lead, leaving an almost imperceptible kink.



FIG. 3



FIG. 4



FIG. 5



FIG. 6

Sitka spruce (*Picea sitchensis* Carr.) in the New Forest, Hampshire.

FIG. 3. A strong undamaged leading shoot, with two side shoots (laterals) of one year's growth. Horizontal distance between tips of laterals, $22\frac{1}{2}$ inches.

FIG. 4. The same after mutilation of the leader, on 13th April 1947.

FIG. 5. The same on 6th July 1947. Horizontal distance between previous tips of laterals reduced to $12\frac{1}{2}$ inches.

FIG. 6. The same on 17th September 1947. Horizontal distance between previous tips of laterals reduced to $5\frac{1}{2}$ inches.

ground level. This figure shows how the kink was originally very pronounced but became almost imperceptible after several years of rapid growth.

Fig. 1 of Plate III is an enlargement of the central part of Fig. 2. It shows that the vertical leading shoot was killed back as far as a pair of lateral shoots, one of which subsequently took the lead. A portion of the dead leader forms an obvious blemish in the timber, and the dark frost rings are clearly visible.

TRANSFORMATION OF LATERAL TO LEADER.

The way in which a lateral shoot, which has been growing horizontally as a lateral for one or more seasons, takes the lead with only a small deflection in the resultant main stem is interesting.

The series of four figures of Plate IV makes this clear and shows the early external features of the growth effect displayed in Plate III, Figs 1 and 2.

Fig. 3. A Sitka spruce with strong leader and two lateral shoots of one year's growth. The horizontal distance between the tips of these laterals, *A* and *B*, is $22\frac{1}{2}$ inches.

Fig. 4. The same, with the leader mutilated, 13 April 1947.

Fig. 5. The same tree on 6 July 1947. The horizontal distance between *A* and *B* is now reduced to $12\frac{1}{2}$ inches.

Fig. 6. The same on 17 September 1947, with the horizontal distance between *A* and *B* only $5\frac{1}{2}$ inches.

CONCLUSIONS.

1. The loss of a leader in Sitka spruce by frost or other agency does not necessarily result in a seriously deformed tree.

2. Resultant deformities are less in rapidly grown trees than in those of slower growth.

3. It takes only one season for a lateral branch to develop into a vertical leader.

NOTE:—The measurements mentioned above and shown in Figs. 5 and 6 are between the selected points *A* and *B*. These points were the tips of the lateral shoots when first measured (Fig. 3) but later remained behind the growing tips, owing to new seasonal growth.

RANDOM AND SYSTEMATIC SAMPLING IN TIMBER SURVEYS

By D. J. FINNEY

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1. INTRODUCTION.

A SAMPLING technique, in forestry as in studies of other material subject to inherent and uncontrollable variation, is neither a device for investing a skimped investigation with a spurious air of respectability nor a mathematician's plaything, of no use to the practical man. Rather is it a precision instrument, giving valuable results when properly employed but liable to be misleading if carelessly handled. In practice, indeed, a well-planned sample will sometimes be more trustworthy than a complete enumeration of the material studied, since the very fact of a sample being used may enforce certain standards of conscientious measurement and recording that might be absent from a complete enumeration: an intelligent and well-instructed staff may obtain more valuable information from a sample of 5-10 per cent. than would a necessarily larger and less expert labour force from a 100 per cent. enumeration, yet the sample should cost substantially less, in time and in money. Deming [1947 (4)] has given an excellent summary of the aims of the sampling method and its advantages over complete enumeration; his illustrations are drawn from types of inquiry other than that to be discussed here, but his statement should interest all who have any concern with sampling problems. Writing of recent experience in India, where 'Partial sampling enumeration was new as a practical proposition', Griffith [1947a (16)] says: 'A very general summary of the actual work done and the opinions of the various working plan officers in charge of parties is that a 5 to 10 per cent. enumeration under average conditions can cover a net area of about 20 to 35 acres per day (i.e. sampling a gross area of from 200 to 700 acres per day). In general such a partial enumeration costs about one third as much as a full enumeration and takes about one quarter of the time to do.'

The general principles of sampling in forest surveys should be familiar to every forest officer; they have been described in considerable detail in an earlier paper [Finney, 1948 (5)]. The statistical computing required in the analysis of sampling data and the assessment of the precision of estimates may at first seem arduous to the inexperienced, but will be trivial by comparison with the field work of the survey and a small price to pay for the reduction in cost and the speedier availability of results. Though the advice of a statistician should be sought wherever possible, the actual analysis will rarely be beyond the powers of a forest officer who has grasped the essential principles. Undoubtedly, however, there are problems connected with forest sampling which require further research by statisticians, and with one of these the present paper is concerned. The writer would like to make clear that, whereas his previous paper was intended as a general

account of the principles of sampling, this describes a piece of statistical research of which probably only the broad outline and conclusions will interest the forest officer.

In the earlier paper [Finney, 1948 (5)] the writer has discussed the conditions under which a sampling procedure for the estimation of volumes of standing timber will provide an unbiased estimate of the total volume for the stand, and also the conditions under which the data from a single sample may be used for assessing the precision of the estimate. For freedom from bias, the sample must be selected according to objective rules, as a random sample (unrestricted or stratified), or as a systematic sample with random selection of the first unit. If the sample is to provide its own assessment of precision, the only completely satisfactory arrangements are either unrestricted random selection or stratified random selection of two or more sampling units from each block. The precision of an estimate from a single systematic sample, or from a random sample of one unit from each block, cannot be assessed from internal evidence by orthodox statistical processes; nevertheless, general argument suggests that the true precision of such samples is likely to be higher than that of either of the other types.

The investigator who plans a sampling survey of a timber stand thus faces a dilemma. Shall he adopt stratified random sampling and follow the precept of small homogeneous blocks so far as is consistent with obtaining a valid estimate of sampling error—that is to say, use blocks of such a size that each contributes two sampling units? Shall he attempt to increase the true precision of his estimate, while keeping the same intensity of sampling, by reducing his blocks to half the size and taking only one unit from each, so sacrificing his assessment of error? Or shall he abandon random sampling in favour of systematic selection of sampling units, a method often more convenient in practice but introducing further complications to be mentioned later, and again lack any assessment of error?

There is no simple answer to these questions. If the increase in precision resulting from either of the two last courses is trivial, the sacrifice of the assessment of error will be scarcely worth while. If the gain is large, there may sometimes be good reasons for taking advantage of it. The possible gain in precision for any particular stand cannot be told without an enumeration, complete or sample, of that stand, but experience of other similar stands may indicate its likely order of magnitude, and so guide the decision of the investigator. Data from complete enumerations of large stands, available in the form of records for each of many small units, are especially valuable as foundations for this experience, since they may be analysed in a multitude of ways corresponding to different sampling schemes.

The complete enumeration of a forest is a costly and laborious undertaking, and existing records of enumerations should therefore be utilized to the full. If analysis of these indicates that systematic sampling generally leads to substantially higher precision, renewed efforts should be made to devise some satisfactory method for the assessment of precision from a single systematic sample. Finney [1948 (5)], Hasel [1942 (19)], and Langsaeter [1932 (20)] have emphasized the danger of the naïve procedure of analysing data from a systematic sample as

though the sampling units had been selected at random. No method can give a valid estimate without assumptions, implicit or explicit, about the nature of variation in volume per unit area over the stand, in addition to those usually summarized by the statistician as 'a normal distribution of random errors'. Cochran [1946 (3)], Hasel [1942 (19)], and Matérn [1947 (22)] have suggested possible mathematical specifications for the type of systematic variation encountered in forest sampling. These necessarily lead to calculations more complicated than for random sampling. Furthermore, there can be no 'mathematical' proof of their suitability: the appeal must always be to their agreement with the facts of complete enumerations of typical stands, and, even then, without long experience there can be little assurance that parameters determined from past enumeration data can be applied to future partial enumerations, by systematic samples, of other forests. Yates [1946 (29)] has suggested other ideas worthy of trial; the results of these also must be compared with true measures of precision in trial samples from complete enumerations. In the immediate future, empirical methods giving full weight to the records of a single sample are perhaps more likely to provide an assessment of error reliable enough for practical purposes than are methods based on theories which can scarcely be adequately tested on existing data. Both are important lines of research, though neither yet enables the statistician to advise the forest investigator satisfactorily about problems of systematic sampling.

The first point to be settled is whether, in fact, systematic sampling is more precise, and, if so, by how much. Yates [1946 (29)] and Finney [1948 (5)] have expressed the opinion that, in forest and other area surveys, systematic sampling will generally be more precise, but the latter has shown that a strongly marked pattern of variation does not necessarily have this consequence, and that, in an area where the pattern was periodic, systematic sampling might be even less precise than some forms of random. Griffith's statement [1947*a* (16)] that for one forest 'The data were arranged by nature systematically and hence the only logical way to sample it was in a systematic manner' is therefore not of universal validity. Griffith [1945*a-g* (6)–(12); 1946*a-c* (13)–(15)] and Hasel [1938 (18)] have collected extensive complete enumeration records and have used these for comparisons of sampling procedures. Each concludes that systematic selection in general gives estimates of higher precision. These authors have very kindly made some of their data available to the present writer for a further analysis, which is in some respects more and in other respects less detailed. The opportunity has been taken to incorporate the 'adjustment for end conditions' in systematic sampling recently recommended by Yates [1946 (29)]. Clearly no final conclusions can be based on data from two stands only, but this paper is presented in the hope that it will stimulate similar detailed analyses by others who have access to suitable data. The terminology used throughout, except in quotation from Griffith and Hasel, is that of the previous paper [1948 (5)], to which reference should be made for fuller explanations of the basic principles of sampling, here assumed familiar to the reader.

2. THE DATA.

(a) *Mount Stuart.*

At a silvicultural conference held at the Indian Forest Research Institute, Dehra Dun, in April 1945, the urgent need for large-scale enumerations in order to gather information on war-time overfelling and remaining resources was discussed. Acknowledging that 'we have little or no information of the potential accuracy of current methods of enumeration', and in the belief that 'much useful information can be obtained by examination of existing data', the conference urged the importance of investigating sampling techniques and testing their efficacy on records of past surveys. A resolution was passed that 'The central silviculturist be authorized to proceed at once with the examination of existing data to endeavour to give an indication as soon as possible of the probable accuracy of different methods and intensities of enumeration of different types of forest and terrain. Approximate information is needed quickly rather than a more detailed accurate complete research' [Griffith, 1945*a* (6)]. In consequence of this resolution, Dr. A. L. Griffith was able to examine many complete and partial enumeration records from different parts of India, and to discuss the reliability of the volume estimates that would have been obtained had these surveys been replaced by various types and intensities of sampling. Within a year he published a series of ten leaflets on the results of his analyses [Griffith, 1945*a-g* (6)–(12), 1946*a-c* (13)–(15); Brasnett, 1946 (1)]. Naturally a programme executed so rapidly could not amount to a 'detailed accurate complete research'. Dr. Griffith has explained [1947*b* (17)] that the urgency of the problem and slowness of publication prevented him from giving a full account of theoretical aspects, and he justly points out that statisticians were unable to give adequate answers to his questions on the theory of systematic sampling. What was vastly more important, from the practical point of view and in the circumstances then obtaining, was 'to give condensed useful information quickly', and this Griffith undoubtedly did; in the process, he amply justified his own contention that sampling was an economical, practicable, and reliable alternative to complete enumeration, and indicated the order of magnitude of the errors to which a sample estimate is subject.

Through the generosity of Dr. Griffith the writer has been enabled to use in this paper the complete data from the most extensive of the enumerations he studied. In the third of his leaflets [1945*c* (8)] he reported the enumeration of an irregularly shaped block of 7,383 acres of forest in South Coimbatore, Madras, classified by Champion as 'Group 3*a*, Southern tropical deciduous forests C1, South Indian moist deciduous'. The climate and floristics are summarized in Griffith's paper. In 1928–31 the area was enumerated by strips of 3 chains in width, at right angles to an east-west base line running roughly along the contours; the trees in each 5-chain length of strip were recorded separately, so giving a recording unit of $1\frac{1}{2}$ acres. 'For each species records were kept of the number of trees by 1-foot breast height girth classes, from 3 feet to 8 feet and over, and also the number of poles up to 3 feet in girth. Breast height girth measurements were converted to volumes from local volume tables, poles being recorded separately.'

The area contained 160 strips. The most easterly strips were 25-30 recording units in length, strips 45 to 68 had 35-40 recording units, after which the area narrowed to 15-20 units for strips 85 to 112, and finally broadened to about 45 recording units for each of the last 30 strips at the west end. Thus the whole area was roughly dumb-bell shaped, and contained a total of 4,921 recording units.¹ It should be pointed out that the data were collected solely as a complete enumeration, many years before the sampling problem arose. The base line and strips were chosen for their practical convenience at that time, and are not necessarily the same as would be recommended for sampling purposes.

The data used for this paper are the total volumes of commercial (saleable) timber, irrespective of species and size of tree, a single figure for each of the 4,921 units. In dense tropical forest of this type the expense of locating and enumerating isolated small units in sufficient number for an adequate sample would be prohibitive, and strip sampling is the only practicable method. The limitation to units which are strips right across the forest simplifies the sampling problem by making it one- instead of two-dimensional. The data may also prove valuable for the study of less restricted sampling schemes, in which sets of recording units other than complete strips might form the sample, but for the present only samples consisting of a number of whole strips will be considered. This paper is concerned with the data as representative of the kind of variation found in natural forest, and not particularly with the optimal method of sampling the Mount Stuart area. A further simplification has been introduced, therefore, by using only the mean volume per acre for each strip and ignoring differences in the numbers of units on which these means are based. Schumacher and Chapman [1942 (27)] have discussed strip sampling with strips of different lengths, but application of their methods to the numerous analyses described later would have been exceedingly laborious. The 'idealized' data, resulting from treatment of mean volumes per strip as though they related to a forest area of rectangular boundary, are equally useful as typifying one-dimensional variation in volumes. Indeed, the conclusions on relative efficiency of different sampling methods are very unlikely to depart much from what would be shown by analyses which weighted each strip in proportion to its length.

(b) *Blacks Mountain Experimental Forest.*

Hasel [1938 (18)] has discussed in considerable detail the relative precisions of various random and systematic sampling schemes in relation to a fully enumerated area of 5,760 acres of virgin timber situated within the Lassen National Forest in north-eastern California. 'The timber type is classed as pure pine, with more than 90 per cent. of the volume in ponderosa pine (*Pinus ponderosa* Dougl.) and Jeffrey pine (*P. jeffreyi* Oreg. Com.).' The area consisted of nine sections, each 80 chains square, arranged as shown in Fig. 1. Each section was enumerated in recording units of 10 chains by 2.5 chains, arranged in 32 east-west strips of 8 units.

The data used here are total volumes of all trees 12 inches or more in diameter,

¹ The discrepancy of 1 acre between this total and the 7,383 acres for the forest is due to the irregular boundaries of the area.

irrespective of species. For the present purpose, only strip sampling has been considered, each strip being of length 80 chains and width 2.5 chains, and the figures analysed are the 288 volumes per strip of 20 acres. This limitation was adopted for two reasons: first for the sake of comparability with the Mount Stuart results;

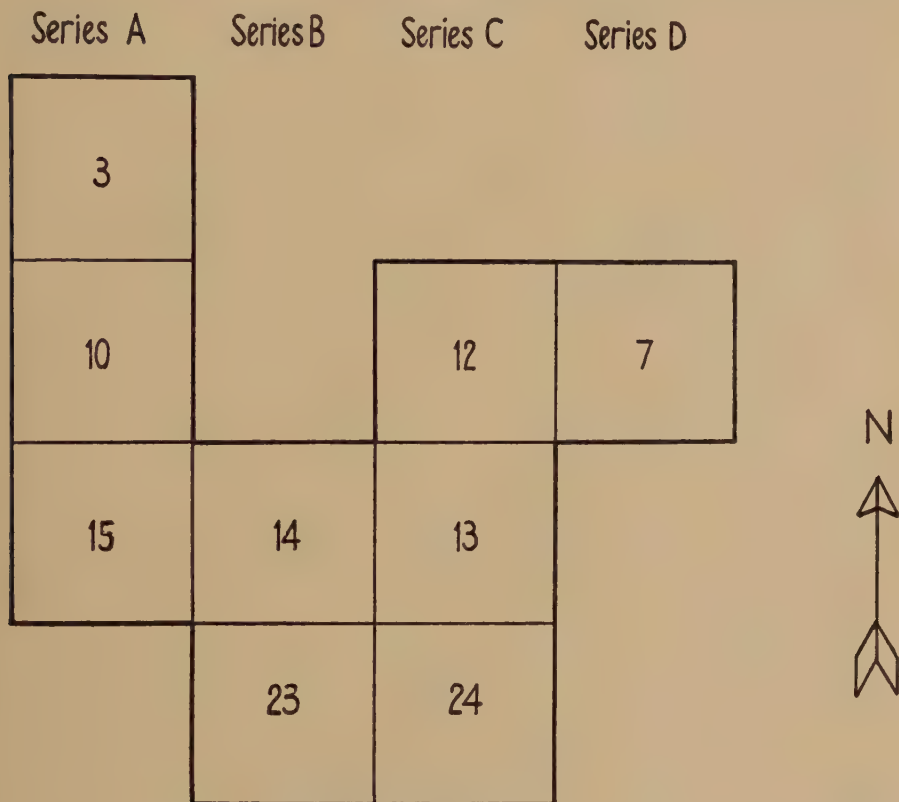


FIG. 1. Diagram showing the relative positions of the nine sections and series *A*, *B*, *C*, *D*, for Blacks Mountain Experimental Forest.

secondly because even these extensive data would be inadequate for an examination of two-dimensional sampling schemes as detailed as that for one-dimensional sampling discussed below. Unlike the Mount Stuart forest, the strips were not in a single line. Since the correlation between adjacent strips is an important factor in the comparison of random and systematic sampling, it would be unfair to regard, say, the southernmost strip of Section 15 (Fig. 1) as followed by the northernmost strip of Section 14. Instead, the area was treated as four series of strips, *A* consisting of the 96 strips in Sections 3, 10, 15, *B* of the 64 strips in Sections 14, 23, *C* of the 96 strips in Sections 12, 13, 24, and *D* of the 32 strips in Section 7. Sampling errors were calculated separately for each series and then combined into averages for the whole area. It is perhaps of interest to note that analyses of variance showed little indication that volumes for strips longitudinally

adjacent (as, for example, corresponding strips of Sections 15, 14, 13) were correlated; these analyses are scarcely relevant to the present theme, and details will not be reported here.

3. PRINCIPLES OF ANALYSIS.

The types of strip sampling have been fully defined in the previous paper [Finney, 1948 (5)], and only a brief summary need be given here. If the forest contains N strips in all, a 1 in r unrestricted random sample requires that N/r (supposed an integer) strips should be chosen entirely at random from the N ; a strictly random process and not mere haphazard selection is important. The purpose of stratification is to ensure a rather more regular spread of sampling units over the forest; for a 1 in r stratified random sample in blocks of N_0 , the N strips are subdivided into successive strata or blocks of N_0 , and N_0/r chosen at random from each block. In so far as is consistent with other requirements, N_0 should be small. A 1 in r systematic sample consists of a set of strips at intervals of r , for example those numbered 7, $(7+r)$, $(7+2r)$, $(7+3r)$, . . .; its complete regularity is often claimed to give a better representative figure for the whole forest than could any random selection procedure. Providing that the first strip of a systematic sample is chosen at random, all these types of sample give unbiased estimates.

The purpose of this paper is to study empirically the relationship between the precisions of random and systematic sampling at different intensities, in the hope of discovering general trends. The examination of two areas alone is not a sufficient basis for general conclusions, and the writer hopes that at some future date he may be able to make similar studies of other forest enumerations. Both Griffith and Hasel restricted their analyses to a small number of different sampling fractions, and Griffith did not consider the possible improvement of the precision of random sampling which might result from stratification. This statement is not intended as derogatory to the work of the two authors: Griffith analysed enumerations of many other forests in order to make urgently needed general recommendations on Indian sampling procedure, and Hasel considered also many types of sampling unit other than the complete strip. The scope of the present investigation may be seen from Section 5, in which are summarized estimations of sampling errors from random and systematic strip sampling of Mount Stuart and Blacks Mountain, with sampling intensity 1 in r , where r ranges from 2 to 32.

In principle the methods of analysis are similar to those used by Hasel. Indeed for random sampling there are only minor modifications, these being necessitated by the inclusion of sampling fractions which do not give an integral number of strips from each of the series A , B , C , D . For systematic sampling the method adopted is again similar to Hasel's comparison of all possible samples for a given intensity, but some complication is introduced by the adjustment for 'centralizing' the samples described in Section 4 below. Attention has been drawn in the previous paper [Finney, 1948 (5)] to the common fault of calculating sampling errors for systematic samples as though the sampling units had been selected independently and at random, and also to the invalidity of methods for the estimation

of any sampling error based on variations between individual recording units within a sampling unit. Unfortunately both these faults mar Griffith's series of leaflets, in part because of the haste in which the analyses had to be performed and in part because of the lack of satisfactory statistical methods for systematic samples.¹ As may be seen from later sections, however, the present analysis does not materially alter his main conclusions, even though the method of arriving at them is different.

The misleading effect of attempting to assess the precision of a systematic sample by formation of the sum of squares between its constituent strips may be seen from consideration of a simple artificial example. Suppose that a forest contained 160 strips in all, and had its pattern of systematic variation so strongly marked that each of strips 1 to 10 had volumes of 500 cu. ft. per acre, each of strips 11 to 20 had 600 cu. ft. per acre, and so on, ending with 2,000 cu. ft. per acre for each of strips 151-60. Suppose further that the mean volume, whose true value is of course 1,250 cu. ft. per acre, is to be estimated from a sample of 1 strip in 10.

- (a) An unrestricted random sample of 16 strips would give a mean whose variance was determined from the variance per strip within the whole population,

$$\sigma^2 = 212,500.$$

The true or expected value for the variance of the sample mean is

$$\sigma_{\bar{x}}^2 = \frac{\sigma^2}{16} \left(1 - \frac{15}{159} \right), \quad \text{by equation (3) below,} \\ = 12,000.$$

In practice, σ^2 would be unknown, and $\sigma_{\bar{x}}^2$ would have to be based on an estimate, s^2 , with 15 degrees of freedom, calculated from variation between sampling units.

- (b) The forest might be stratified into, say, the four strata of 40 strips formed by numbers 1-40, 41-80, 81-120, 121-60. A 1 in 10 stratified random sample would consist of 4 strips chosen at random within each stratum. The variance per strip within strata is

$$\sigma^2 = 12,500,$$

whence, by the same formula as for (a),

$$\sigma_{\bar{x}}^2 = 720.$$

¹ 'In default of an obvious method more suitable, in order to work out a precision for our estimates, we applied the statistical methods evolved for the analysis of random samples to the systematically arranged data of the partial enumerations. We were forced to do this because statistical methods applicable to the systematic sampling of the systematically arranged data have never been worked out' [Griffith, 1947a (16)]. The reader, whether statistician or not, who has encountered the difficulties in any rigorous treatment of systematic sampling will sympathize with the second sentence of this quotation. Nevertheless, it is scarcely just to the type of investigation that has been made by Hasel, nor does it explain the use of a method (that of treating parts of strips as though they were independent recording units) that would still be inappropriate for random strip sampling.

A single sample would provide an estimate of its own variance based on 12 degrees of freedom.

- (c) The increase in precision resulting from stratification could be made still greater by using 8 strata of 20 strips, and taking 2 strips at random from each stratum. The variance per strip within strata is

$$\sigma^2 = 2,500,$$

whence

$$\sigma_{\bar{x}}^2 = 150.$$

A single sample would still provide its own estimate of variance, now with 8 degrees of freedom.

- (d) The extreme form of stratification would be that into 16 strata of 10 strips, taking 1 strip at random from each stratum. The variance per strip within strata is now zero, and consequently $\sigma_{\bar{x}}^2$ is zero, since the sixteen sampling units must give the volumes 500, 600, 700, . . . , 2,000 in that order. Nevertheless, if data from only a single sample are available, estimation of the variance per strip within strata is impossible: there are no degrees of freedom for the estimate.
- (e) A systematic sample consisting of every tenth strip must also give the sixteen values 500, 600, 700, . . . , 2,000, and consequently again the true value of $\sigma_{\bar{x}}^2$ is zero. The complication of centralizing the sample (see below) can be ignored, as it has no effect in this sample. When data from only a single sample are available, the variance cannot be estimated. If an attempt were made to base an estimate on a sum of squares between the sampling units, a value for the variance per strip would be obtained as

$$s^2 = \left[500^2 + 600^2 + \dots + 2,000^2 - \frac{(200,000)^2}{160} \right] \div 15 \\ = 227,000;$$

this leads to a supposed estimate of the variance of $\bar{x}$,

$$s_{\bar{x}}^2 = 12,800,$$

larger than that for unrestricted random sampling! The same $s_{\bar{x}}^2$ would arise, of course, if a variance for method (d) were assessed from variation between sampling units from different strata.

The example discussed is artificial, but it shows that the circumstances in which the increase in precision resulting from extreme stratification or from systematic sampling is greatest (as compared with unrestricted random or less extreme stratified random sampling) may also be those in which uncritical assessment of sampling error from a sum of squares between all units of a sample is most seriously misleading. If he assumes that periodicity effects such as have been discussed in the previous paper do not occur, the investigator may assert that the true sampling error is not greater than that assessed as in (e),

but the statement is of little value if the true error is only a small fraction of this upper limit. On the other hand, had the same 160 strip values been arranged in random order, any of the forms of sampling just described would have had σ_x^2 the same as for unrestricted random sampling: under circumstances in which systematic sampling leads to no real increase in precision, a sampling error assessed from the sum of squares between strips of the sample may be free of bias.

The two forms of stratified random sampling most useful for the reduction of sampling variances, by comparison with unrestricted random sampling, have been discussed previously [Finney, 1948 (5)]. For any specified intensity of sampling, say, 1 in r , the first of these requires subdivision of the forest into blocks of $2r$ sampling units and the random selection of 2 units from each block. Not only does this scheme make nearly the best possible use of the general principle that intra-block variance decreases as block size is decreased, but it permits the estimation of the intra-block or sampling variance, from differences between pairs of units from the same block: the precision of the sample estimates of mean volume can be assessed from the internal evidence of a single sample. The second scheme uses blocks of r sampling units, with one unit selected at random from each block. The blocks are smaller than in the first scheme, and the sampling variance is therefore in general reduced: the estimate will be more precise. Unfortunately, however, a single sample no longer provides data from which the precision can be assessed. Both schemes have their uses, and when complete enumeration data are available the true sampling error of either can be studied.

4. METHODS OF ANALYSIS.

For a sampling intensity of 1 in r , then, three types of random sampling need consideration, unrestricted selection, stratification into blocks of $2r$, and stratification into blocks of r . The total variance per strip within the whole area, from which will be derived the sampling error of an estimate based on unrestricted random sampling, will be denoted by σ_I^2 , that within blocks of $2r$ by σ_{II}^2 , and that within blocks of r by σ_{III}^2 . It is convenient to regard these variances as relating to a hypothetical infinite population of strips, of which the N forming the forest examined are only a part. The adjustments to sampling errors required in order to allow for the fact of any sampled forest containing only a finite number of strips may then be applied in simple form to the estimates of the variances per strip, as described at the end of this section; confusion over degrees of freedom and a danger of including the adjustment twice are thereby avoided.

Of these variances, σ_I^2 is clearly independent of the intensity of sampling, while σ_{II}^2 and σ_{III}^2 will vary with block size. An estimate, s_I^2 , of σ_I^2 may be formed, in the familiar manner, from the total sum of squares of deviations for all strips. If N , the total number of strips in the data (for Mount Stuart 160, for Blacks Mountain the total in one of the four series A, B, C, D), is an exact multiple of r , the data may be subdivided into N/r blocks of r ; a mean square derived from intra-block variations, s_{III}^2 , is then an estimate of σ_{III}^2 . Such calculations are conveniently arranged in an analysis of variance table [Cochran, 1939 (2)]. For example, for

Mount Stuart, an analysis of variance gives (for details of units of measurement see Section 5):

Source of variation	Degrees of freedom	Sum of squares
Between blocks of 32	4	9,288,000
Within blocks of 32, between blocks of 16	5	2,486,000
Between blocks of 16	9	11,774,000
Within blocks of 16, between blocks of 8 .	10	511,000
Between blocks of 8	19	12,285,000
Within blocks of 8, between blocks of 4 .	20	1,140,000
Between blocks of 4	39	13,425,000
Within blocks of 4, between blocks of 2 .	40	867,000
Between blocks of 2	79	14,292,000
Within blocks of 2	80	1,205,000
TOTAL	159	15,497,000

From the analysis of variance are derived

$$s_I^2 = 15,497,000 \div 159 \\ = 97,500,$$

and the following estimates of σ_{III}^2 :

$$\begin{aligned} \text{for } r = 2: s_{III}^2 &= 1,205,000 \div 80 &= 15,100, \\ \text{for } r = 4: s_{III}^2 &= (15,497,000 - 13,425,000) \div 120 &= 17,300, \\ \text{for } r = 8: s_{III}^2 &= (15,497,000 - 12,285,000) \div 140 &= 22,900, \\ \text{for } r = 16: s_{III}^2 &= (15,497,000 - 11,774,000) \div 150 &= 24,800, \\ \text{and for } r = 32: s_{III}^2 &= (15,497,000 - 9,288,000) \div 155 &= 40,100. \end{aligned}$$

Values of r which are not factors of N could not be treated quite so simply. For them, one of two courses was adopted: either a few strips at each end of the forest were omitted, so that the remaining number was a multiple of r , or two separate analyses were made and the results averaged. For example, omission of two strips at each end of Mount Stuart left 156, and these were used in an analysis of variance to give s_{III}^2 for $r = 3, 6$, and 12; the omissions are too few to have any important effect. Again, separate analyses for strips 1 to 150 and for strips 11 to 160 each led to values for $r = 25$ and 50, and the average of corresponding mean squares was adopted as s_{III}^2 ; this involves a slight under-weighting of the evidence from strips at the two ends, but again the effect will be small. Series *A, B, C, D*, of Blacks Mountain were analysed separately by a similar procedure, after which weighted averages for the whole area were constructed, using weights proportional to the number of strips per series, 3:2:3:1. As is obvious from the definition of the symbols, σ_{II}^2 for any r is identical with σ_{III}^2 for $2r$, and therefore s_{II}^2 , the estimate of σ_{II}^2 , may be taken as the value of s_{III}^2 for $2r$. No more need be said about the method of calculation of random sampling variances, for it must be familiar to all who have dealt with sampling problems; the results are summarized in Tables I and II.

A common practice in the examination of complete enumeration data for the

study of the precision of systematic sampling is to form the set of all possible 1 in r systematic samples with regular spacing, and to find the variation between the members of this set. For 1 in 12 sampling, for example, the totals of strips $1+13+25+\dots$, strips $2+14+26+\dots$, strips $3+15+27+\dots$, would be formed. The sum of squares of deviations between the twelve totals then leads to an estimate of the variance per strip, appropriate to a 1 in 12 sample in which the first strip is selected at random from numbers 1, 2, 3, $\dots$, 12. This is the method used by Hasel [1938 (18)]. It has two disadvantages. However extensive the data, the estimate of variance for 1 in r sampling is based on only $(r-1)$ degrees of freedom; for reliable comparisons of systematic with random sampling even the 19 degrees of freedom available for 5 per cent. sampling can scarcely be regarded as adequate. Secondly, if there happens to be a marked trend in volume per unit area from strips at one end of the forest to those at the other, random selection of the first strip will give undue dispersion to the estimates obtained by repeated sampling. For example, suppose that volumes increased fairly steadily from strip 1 to the final strip, N . If the first strip of a 1 in r systematic sample occurs before the position $\frac{1}{2}r$, each strip in the sample will tend to be below the average for the corresponding block of r , and the estimate of mean volume will tend to be low; if the position of the first strip is later than $\frac{1}{2}r$, the estimate will tend to be high. This is not a bias, for in repeated sampling the effect would average out, but it might lead to serious loss of precision in a forest in which the trend was strongly marked.

In the past, much emphasis has been placed upon the importance of random selection of the first strip (or other sampling unit) in order that a systematic sample be unbiased. As has been explained in the previous paper [Finney, 1948 (5)], strictly this is necessary, but often a small bias in estimation for a particular forest may be unimportant providing that the sampling procedure is such as to give no bias over a series of forests. A systematic sample which *by rule* consisted of the middle strip from each successive block of r is biased; repetition of the sampling procedure would not lead to the true mean volume as an average value, since all samples so obtained would be identical! In a series of samplings of different forests, however, this type of bias should average out (though the possibility of a consistent effect of marginal strips has been noted in the earlier paper). If a systematic sampling scheme is chosen, in spite of the consequent impossibility of assessing the sampling error from the evidence of the sample alone, there is some case for deliberately taking the middle strip of each block of r (or one of the two middle strips when r is even), rather than basing the sample on a random first strip, in order to avoid the loss of precision of a non-central sample. Alternatively, use of a random first strip might be followed by a centralizing adjustment for the whole sample analogous to that described below, so as to remove the component of variance due to deviations from block centres. In a study of the merits of systematic sampling the procedure should be shown to best advantage by applying such a centralizing adjustment to all the possible samples from a complete enumeration.

The arithmetical technique for dealing with these two points is simple, though

the calculations required in a full examination of any one complete enumeration are laborious. In order to obtain more degrees of freedom for the estimation of variance, the whole series of strips may be broken into smaller groups; the variance may then be assessed for each group, and later combined into an average value for the whole. The groups need not be independent, and may overlap without producing any bias in error estimation, though of course the total number of degrees of freedom used in the calculation will not then be an indicator of the reliability of the result. There may indeed be some slight inequality of weighting of evidence from different parts of the area as a result of the overlap of groups, but unless the variance itself varies markedly between parts, the effect will be trivial. Care should be taken to choose a fairly symmetrical system of overlapping groups. The calculations, including the centralizing adjustment, can most easily be understood from consideration of an example.

The mean volumes per acre for the strips of Mount Stuart may be denoted by $x_1, x_2, x_3, \dots, x_{160}$. Consider systematic sampling, at an intensity of 1 in 12, of the first 59 strips. A centralized sample will then be adjusted so as to relate to the position of strip 30, after the removal of the effect of any linear trend in the first 59 values. The adjusted totals for the 12 possible samples are [cf. Yates, 1946 (29)]:

$$\begin{array}{c}
 x_{12} + x_{24} + x_{36} + x_{48} \\
 \frac{1}{12}x_1 + x_{13} + x_{25} + x_{37} + \frac{11}{12}x_{49} \\
 \frac{2}{12}x_2 + x_{14} + x_{26} + x_{38} + \frac{10}{12}x_{50} \\
 \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \\
 \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \\
 \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \\
 \frac{10}{12}x_{10} + x_{22} + x_{34} + x_{46} + \frac{2}{12}x_{58} \\
 \frac{11}{12}x_{11} + x_{23} + x_{35} + x_{47} + \frac{1}{12}x_{59}
 \end{array}$$

A sum of squares of deviations may then be calculated for these 12 totals, the result being 817,900 (11 degrees of freedom). The calculations are repeated with another group, which may overlap the first, say, strips 11 to 69, using the totals

$$\begin{array}{c}
 x_{22} + x_{34} + x_{46} + x_{58} \\
 \frac{1}{12}x_{11} + x_{23} + x_{35} + x_{47} + \frac{11}{12}x_{59} \\
 \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \\
 \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \\
 \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \\
 \frac{11}{12}x_{21} + x_{33} + x_{45} + x_{57} + \frac{1}{12}x_{69}
 \end{array}$$

to give another sum of squares with 11 degrees of freedom. So further groups are used, and the results are summarized as:

<i>Sampling of 1 in 12.</i>	<i>Totals of 4. Groups of 59</i>
<i>Group</i>	<i>Sum of squares</i>
1-59	817,900
11-69	720,600
21-79	487,500
31-89	292,300
41-99	529,200
51-109	588,100
61-119	908,200
71-129	1,105,500
81-139	626,100
91-149	487,600
101-159	898,400
TOTAL	7,461,400

The 11 groups provide in all 121 degrees of freedom and give a mean square $7,461,400 \div 121$, or 61,660. Since the totals from which the sums of squares are calculated are 'totals of 4 strips', the mean square might at first be thought to estimate $4\sigma_{IV}^2$, where σ_{IV}^2 is the variance per strip in this type of systematic sampling; the fact that most of the totals contain two fractions of strip values, however, reduces the variance slightly, and the mean variance of the 12 totals in a set may easily be shown to be $1,585\sigma_{IV}^2/432$ or $3.669\sigma_{IV}^2$. The general formula for sampling at an intensity of 1 in r , and using totals of k strips in the manner just illustrated with $k = 4$, is

$$\text{Expectation of mean square} = \left(k - \frac{r^2 - 1}{3r^2}\right)\sigma_{IV}^2. \quad (1)$$

Hence an estimate of σ_{IV}^2 in the illustration is s_{IV}^2 where

$$3.669s_{IV}^2 = 61,660$$

or

$$s_{IV}^2 = 16,800.$$

Of course, since the groups overlap, this estimate is not as reliable as if it were based upon 121 independent degrees of freedom. On the other hand, it is certainly much better than an estimate based on 11 degrees of freedom only, and probably appreciably better than an estimate based on 30 independent degrees of freedom (a value obtained as $11 \times \frac{160}{59}$). Similar calculations were made for each of a series of values of r from 2 to 32.

The choice of k , the number of strips to be included in the partial totals, is arbitrary. Too large a value would make the groups, which consist of $(rk + r - 1)$ strips, large and so prevent many being obtained; too small a k would fail to give the advantage of systematic spacing of the strips in the sample sufficient opportunity of demonstrating itself. For Mount Stuart, $k = 4$ was chosen. For the Blacks Mountain data, groups with $k = 3$ fitted more conveniently into the series *A*, *B*, *C*, *D*. Again variance estimates were formed from independent calculations in the four series, and were afterwards combined in proportions 3:2:3:1.

The variances described in this section have been defined as variances per strip

of a sample. If $\bar{x}$ is an estimate of mean volume per acre, obtained as a mean of n strips, its variance may be taken as

$$\sigma_{\bar{x}}^2 = \sigma^2/n, \quad (2)$$

providing that the sampling fraction is small. The correct value, and the one which has been used in the calculations of this paper, makes allowance for the fact that the n strips form an appreciable proportion of N , the total number of strips in the forest. It is

$$\sigma_{\bar{x}}^2 = \frac{\sigma^2}{n} \left(1 - \frac{n_0 - 1}{N_0 - 1} \right), \quad (3)$$

where N_0 is the total number of plots per block, n_0 the number of plots per block taken for the sample; these numbers become N and n for unrestricted random sampling, and

$$\frac{N}{n} = \frac{N_0}{n_0} = r.$$

The modification makes $\sigma_{\bar{x}}^2$ tend to zero, whatever the value of σ^2 , when the intensity of sampling approaches 100 per cent. at which point $n_0 = N_0$. An advantage of re-defining σ^2 so that it relates to an infinite population, as described at the beginning of this section, is that equation (3) then takes the form

$$\sigma_{\bar{x}}^2 = \frac{\sigma^2}{n} \left(1 - \frac{n}{N} \right).$$

Hence, when σ^2 is replaced by an estimate, s^2 , the estimated variance of the mean volume per acre from a sample of n strips is

$$V(\bar{x}) = \frac{s^2}{n} \left(1 - \frac{1}{r} \right), \quad (4)$$

the formula which has been used in Section 6. Any centralizing adjustments to a systematic sample will not seriously affect the formula.

Several methods of comparing the variances are discussed in Section 6.

5. THE ESTIMATES OF VARIANCES.

(a) *Mount Stuart.*

The volume for each of the 160 strips was expressed as cubic feet per acre. All preliminary calculations were performed in terms of this unit, though in the final stages of analysis results were expressed in percentages, for ease of comparison with other data. The strips showed a general fertility gradient from about 600 cu. ft. per acre at the eastern end to about 1,600 cu. ft. per acre at the western end. The mean for all strips (not weighted according to strip length) was 1025.5 cu. ft. per acre.

The method of estimation of variances for different types of sampling has been described in Section 4. For unrestricted random sampling from the whole area

$$s_1^2 = 97,500. \quad (5)$$

Estimates of variance for the two types of stratified random sampling, and for systematic sampling, at intensities of 1 strip in r and with r ranging from 2 to 32, are given in Table I. The value of s_{II}^2 for any r is the same as s_{III}^2 for $2r$.

TABLE I. *Estimates of variance per strip for Mount Stuart, for sampling of*
I in r[In units of (cu. ft. per acre)², and to nearest 100.]

r	s_{II}^2	s_{III}^2	s_{IV}^2
2	17,300	15,100	17,300
3	20,900	17,200	11,400
4	22,900	17,300	15,800
5	24,600	21,400	18,300
6	26,700	20,900	16,900
7	30,100	21,900	18,000
8	24,800	22,900	24,700
9	37,100	24,700	22,600
10	30,500	24,600	21,100
12	34,300	26,700	16,800
14	38,300	30,100	20,000
15	37,900	30,800	20,600
16	40,100	24,800	23,900
18	39,200	37,100	26,200
20	32,400	30,500	26,100
22	..	..	36,000
24	44,900	34,300	51,100
25	44,900	34,600	48,500
26	..	..	50,200
28	49,500	38,300	42,400
30	46,400	37,900	35,600
32	50,900	40,100	38,700

No random sampling estimates were calculated for $r = 22$ and $r = 26$.

From inspection of Table I, s_{IV}^2 is seen to be fairly consistently less than s_{II}^2 and s_{III}^2 , though the difference between s_{III}^2 and s_{IV}^2 is usually small. Thus there seems to be little doubt that systematic sampling of this area would give a more precise estimate of volume than random sampling at the same intensity with two units per block. Apparently most of the improvement is due to the reduction in effective block size, for random sampling with blocks of half the size and one unit per block is almost as good as systematic. Any of these three sampling procedures is very much better than unrestricted random sampling, of course, as may be seen from comparison of the variances for any r with the large s_I^2 .

Though Table I makes apparent these general conclusions, changes in the variances with increasing r are very irregular. The data are not sufficiently extensive for reliable variance estimates to be formed in this way. Before attempting to make quantitative comparisons between the sampling procedure, therefore,

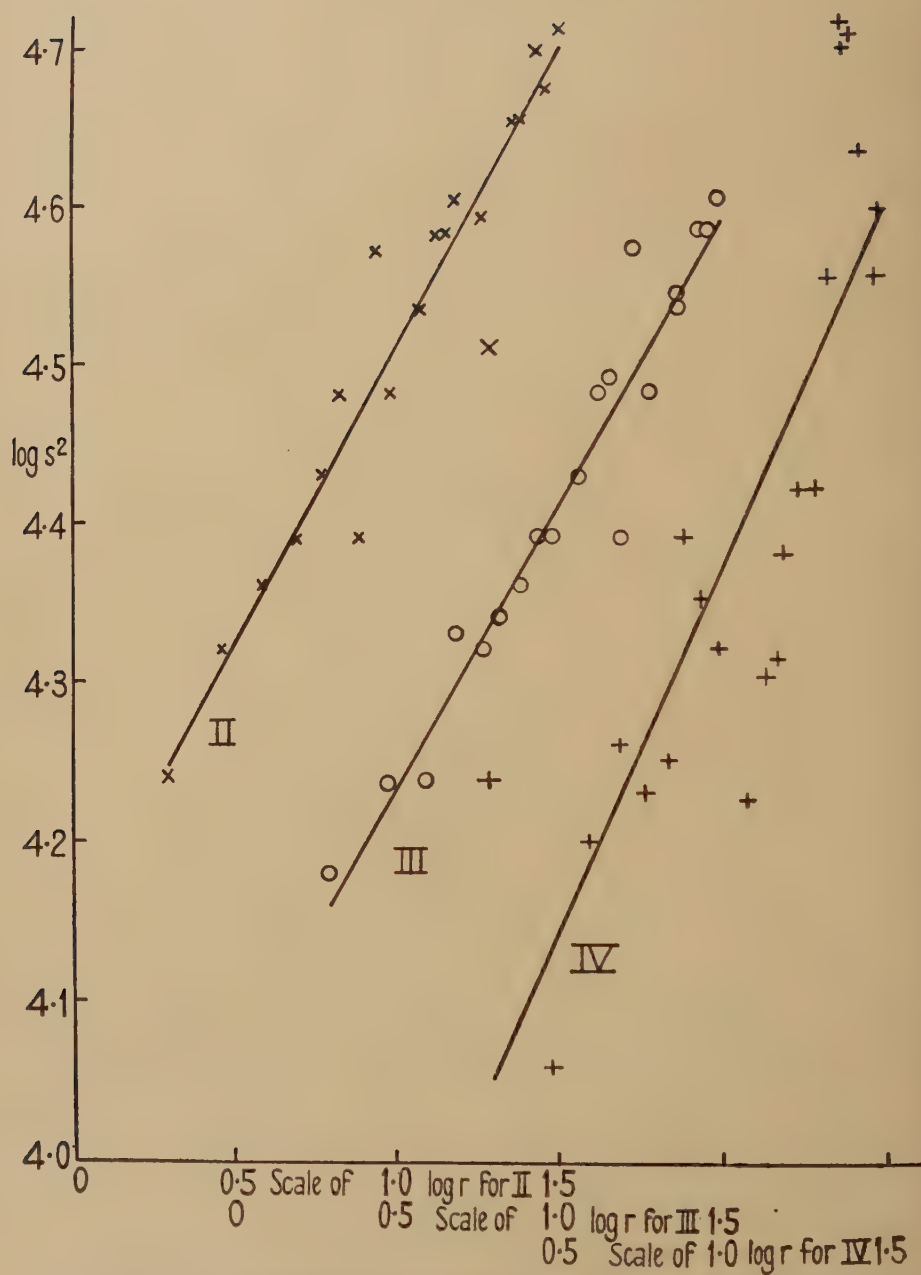


FIG. 2. Mount Stuart: Relationship between variance, s^2 , and r , where the intensity of sampling is 1 in r .

$\times s^2_{II}$ $\circ s^2_{III}$ $+ s^2_{IV}$

some smoothing of the figures in Table I is desirable. Fig. 2 shows that, for each of the three columns, the regression of $\log s^2$ on $\log r$ is approximately linear over the ranges of values studied; since the sampling fraction is $1/r$, this might equally well be regarded as a linear regression on the logarithm of the sampling fraction. The relationship, which is even more close for the Blacks Mountain data (Fig. 3), is empirical, and no theoretical basis is claimed for it; nevertheless, it is interesting to compare this finding with Smith's [1938 (28)] suggestion of a logarithmic relationship between variance and plot or block size in agricultural field experiments. At best, perhaps, the regressions represent a reasonable approximation to a general law, but they are a considerable help for the immediate purpose. Determination of the right weights to be attached to the empirical values of $\log s^2$ is impracticable, and the values for different r and any one sampling procedure cannot be regarded as statistically independent. All that is wanted, however, is an objective method of fitting straight lines to the sets of points in Fig. 2, for which unweighted linear regression equations of $\log s^2$ on $\log r$ have been used.

The lines are shown in Fig. 2; their equations are

$$\left. \begin{aligned} \log S_{II}^2 &= 4.1395 + 0.3655 \log r \\ \log S_{III}^2 &= 4.0548 + 0.3523 \log r \\ \log S_{IV}^2 &= 3.9169 + 0.4479 \log r \end{aligned} \right\}, \quad (6)$$

where S^2 is the smoothed estimate of the corresponding σ^2 provided by the regression. The method of calculation of s_{II}^2 and s_{III}^2 indicates that the true regressions of their logarithms on $\log r$ should be identical except for a horizontal shift of $\log 2$: s_{II}^2 for any r is the same as s_{III}^2 for $2r$. The fitted regression lines are not parallel, however, because they have been obtained from different sets of values, each series relating only to r between 2 and 32. It seems better to adopt the regression equations as independently calculated for the range of observations, rather than to constrain the two to parallelism at a fixed distance apart. For unrestricted random sampling, no smoothing of values is possible, and s_I^2 is taken as the same as s_I^2 in equation (5).

(b) Blacks Mountain Experimental Forest.

Since the 288 strips were all of the same size, the total volume per strip of 20 acres was a convenient unit for analysis; this quantity was measured in thousands of feet board measure. In series *A* the volumes showed a steady decrease from north to south over the first 40–50 strips, then an increase, and finally a further marked decrease at the southern end, the mean for the whole series being 304 thousand board feet. Series *B*, with a mean of 330 thousand board feet, showed a less clear increase from north to south. Series *C*, with a mean of 324 thousand board feet, also showed a volume increase from north to south. The volumes in series *D* were considerably higher, with a mean of 396 thousand board feet, and the series was too short for any clear trend to appear. The mean of the 288 strips was 326.6 thousand board feet.

A sum of squares of deviations with 287 degrees of freedom led to an estimate of variance for unrestricted random sampling

$$s_I^2 = 6,020. \quad (7)$$

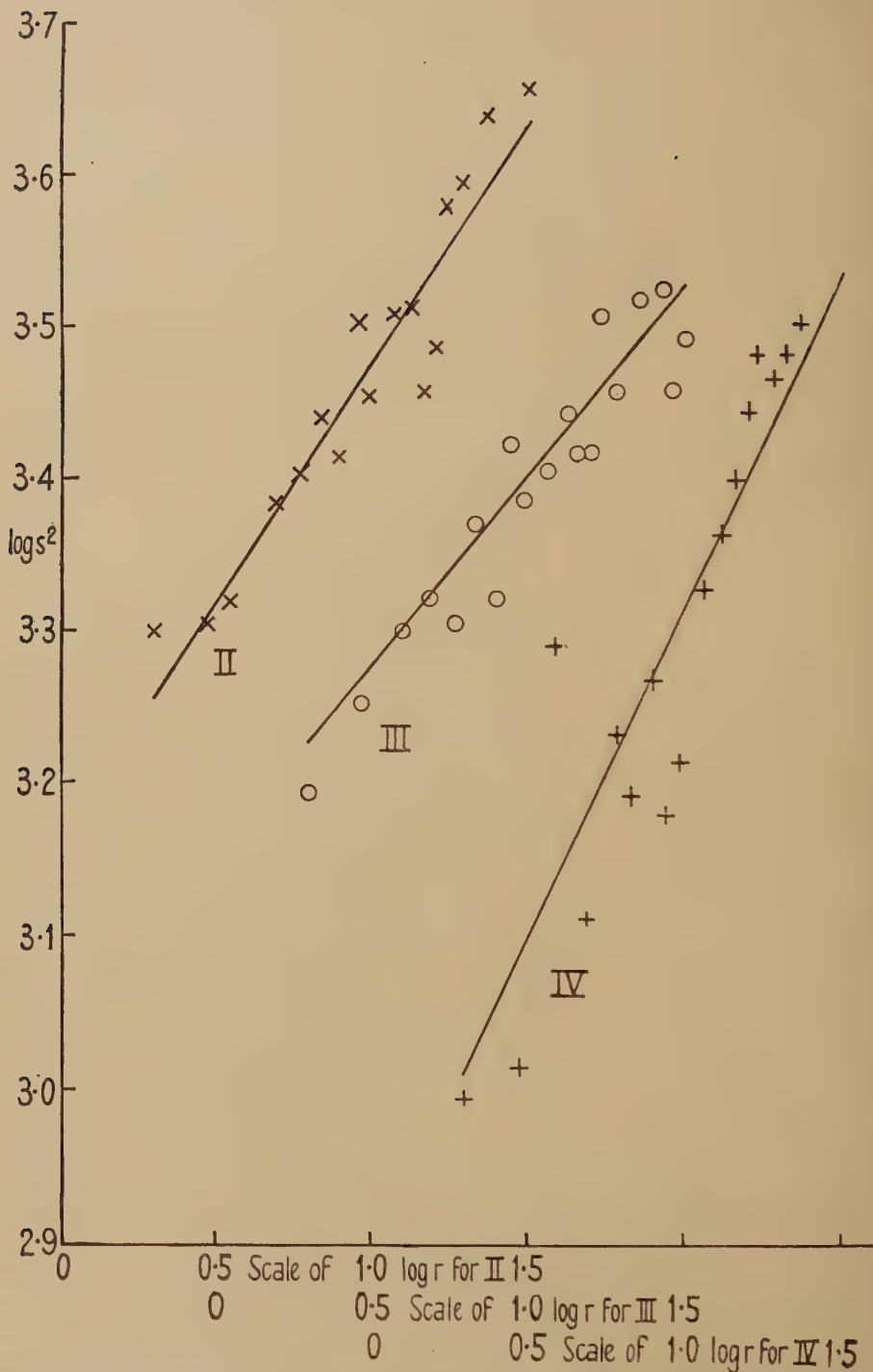


FIG. 3. Blacks Mountain: Relationship between variance, s^2 , and r , where the intensity of sampling is 1 in r .

$\times s^2_{II}$ $\circ s^2_{III}$ $+ s^2_{IV}$

Estimates of variance per strip for the two types of stratified sampling were formed separately for each of the four series, but these will not be shown here. In general, estimates for D were rather higher than the corresponding figures for A , B , and C , with little consistent difference between the others. As stated in Section 4, the variances for the four series were averaged in the proportions 3:2:3:1; for example, for 1 in 10 sampling, the estimates for s_{III}^2 were 2,170; 2,460; 2,230; and 3,550 respectively, and the average was

$$s_{III}^2 = (3 \times 2,170 + 2 \times 2,460 + 3 \times 2,230 + 3,550) / 9 \\ = 2,410.$$

These averages are shown in Table II.

TABLE II. *Estimates of variance per strip for Blacks Mountain, for sampling of 1 in r*

[In units of (1,000 board feet per 20 acres)², and to nearest 10.]

r	s_{II}^2	s_{III}^2	s_{IV}^2
2	1,990	1,560	970
3	2,010	1,800	1,380
4	2,080	1,990	1,940
5	2,410	2,080	1,290
6	2,520	2,010	1,700
7	2,740	2,330	1,530
8	2,580	2,080	1,840
9	3,170	2,620	1,510
10	2,790	2,410	1,630
12	3,200	2,520	2,110
14	3,220	2,740	2,280
15	2,830	2,580	2,440
16	3,040	2,580	2,740
18	3,750	3,170	3,000
20	3,890	2,790	2,880
22	..	..	2,990
24	4,320	3,200	3,130
28	..	3,220	..
30	..	2,830	..
32	4,470	3,040	..

Calculations of some variance estimates for large r were omitted.

Estimates of s_{IV}^2 , for each series separately, were calculated by the same process as for Mount Stuart, except that groups of $(4r-1)$ strips (i.e. $k=3$) instead of $(5r-1)$ were used. In this way estimates from series D could be obtained only for sampling at an intensity of 1 in 8 or higher, and for series B only for 1 in 16 or higher, because of the smaller numbers of strips in these series. Since s_{IV}^2 tended

to be lower for D than for the other series and, at least for large r , greater for B than for A and C , allowance for these omissions had to be made in forming the averages over all series. Inspection of the figures showed that simple adjustments, based on average ratios of variances at sampling intensities for which all series were represented, were sufficient for practical purposes. Indeed the values so obtained, and shown in Table II, are not very different from what would be given by a simple averaging of A and C , ignoring B and D ; presumably inclusion of B and D will have made the estimates a little more trustworthy.

As for Mount Stuart, s_{IV}^2 is seen to be much smaller than s_{II}^2 , and also less than s_{III}^2 for small r , but for higher values of r it approaches equality with s_{III}^2 . Once again any of the sampling procedures II, III, IV gives a variance much lower than that for unrestricted random sampling, s_I^2 . It has been mentioned earlier that the Blacks Mountain data show linear regressions of $\log s^2$ on $\log r$. Fig. 3 represents these regressions derived from the contents of Table II; the regression equations are

$$\left. \begin{aligned} \log S_{II}^2 &= 3.1616 + 0.3101 \log r \\ \log S_{III}^2 &= 3.1516 + 0.2445 \log r \\ \log S_{IV}^2 &= 2.8794 + 0.4296 \log r \end{aligned} \right\}, \quad (8)$$

where again S^2 is henceforward to be used as a smoothed estimate of σ^2 . For unrestricted random sampling, S_I^2 is taken equal to s_I^2 from equation (7).

6. THE COMPARISON OF SAMPLING PROCEDURES.

The derivation of estimates of sampling variance per strip for various sampling procedures has been described in Sections 5 and 6. For the two forests under discussion, equations (5) and (7) give estimates of S_I^2 , the variance per strip in unrestricted random sampling. At a sampling intensity of 1 in r , Method I requires that a fraction $1/r$ of the total number of strips be selected entirely at random, and enumerated. Equations (6) and (8) give smoothed estimates of variance per strip for three other sampling procedures, these estimates being dependent upon r . Method II is a stratified random sampling, in which the forest is divided into blocks of $2r$ consecutive strips and two strips are selected at random from each block. Method III is a stratified random sampling using blocks of r consecutive strips, from each of which one strip is selected at random. Method IV is a systematic sampling, in which every r th strip is enumerated and a 'centralizing adjustment' (Section 4) is applied to the whole sample. The general principles underlying these four procedures have been discussed previously [Finney, 1948 (5)]. In this section, the four will be compared in several ways, in order to show their relative merits in relation to sampling intensity.

The *efficiency* of systematic sampling relative to any other form is defined as the ratio of the precisions (measured by the reciprocals of the variances [Finney, 1948 (5)]) of estimates obtainable at any specified sampling intensity. This ratio will be the inverse ratio of the corresponding variance estimates per strip, since, according to equation (4), each figure for the precision will introduce the same

factors arising from the number of strips in the sample and the intensity of sampling. Expressed as a percentage, the efficiency is

$$E = 100S^2/S_{IV}^2, \quad (9)$$

where, in the numerator, the variance of any of the first three sampling procedures is to be inserted. Both for Mount Stuart and for Blacks Mountain, and at all values of r , S_{IV}^2 is very much less than S_r^2 , so that the efficiency of systematic sampling relative to unrestricted random is high. Figs. 4 and 5 show the efficiency relative to the two types of stratified sampling, for Mount Stuart and Blacks Mountain respectively. Type II stratification vastly improves the precision, as compared with unrestricted random sampling, but leaves a considerable advantage for the systematic, which shows an increase of efficiency by 60–80 per cent. for very intensive sampling, falling to rather less than 30 per cent. in the useful range of sampling, at intensities below 1 in 20. For Type III stratification an appreciable advantage remains with systematic selection at low levels of r , especially with the Blacks Mountain data for which the relative efficiency of the systematic is still as much as 160 per cent. for $r = 2$. When the sampling intensity is reduced to 1 in 20 or less, however, the merit of systematic sampling appears to rest entirely in its reduction of the effective block size from $2r$, under Type II, to r ; the estimated difference between Types III and IV is trivial and probably does not indicate any real advantage for either. The agreement between the diagrams for the two forests is very satisfactory.

The relative efficiency is a comparison between precisions obtainable with different sampling procedures at a specified intensity. Because of the factor $(1 - 1/r)$ in the expression for $V(\bar{x})$, equation (4), the efficiency does not exactly indicate the relative sizes of sample required in order to obtain a specified precision. From some points of view, the latter is the more useful comparison to make, as the size of sample will be closely related to the cost, and one of the chief problems facing an investigator is how to obtain a specified precision most economically. A sample of 1 in r out of a total of N strips will consist of N/r strips (one of the integers adjacent to N/r if this is not itself an integer, but the effect of this modification will be negligible for large N), so that, from equation (4),

$$\begin{aligned} V(\bar{x}) &= \frac{rS^2}{N} \left(1 - \frac{1}{r}\right) \\ &= S^2(r-1)/N, \end{aligned} \quad (10)$$

in which expression the appropriate variance per strip is to be substituted for S^2 . Consequently the precision is inversely proportional to $S^2(r-1)$. If a procedure for which the variance per strip is S^2 at a sampling intensity 1 in r' is to give an estimate of precision equal to that of 1 in r systematic sampling, S^2 and r' must satisfy

$$S^2(r'-1) = S_{IV}^2(r-1). \quad (11)$$

Equation (11) cannot be solved directly to give r' in terms of r , since S^2 is itself dependent on r' (except for S_r^2). For the two types of stratified sampling, however, a graphical solution can easily be devised, making use of equations (6) or (8) to

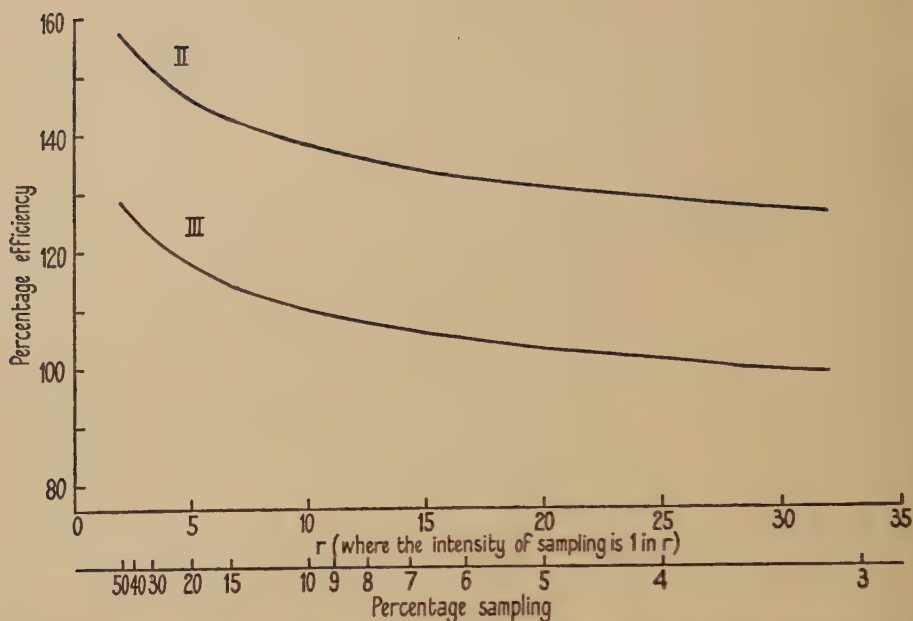


FIG. 4. Mount Stuart: Efficiency of systematic sampling, IV, relative to stratified random, II and III, at different intensities of sampling. (See page 85 of text.) Upper curve: IV relative to II; lower curve: IV relative to III.

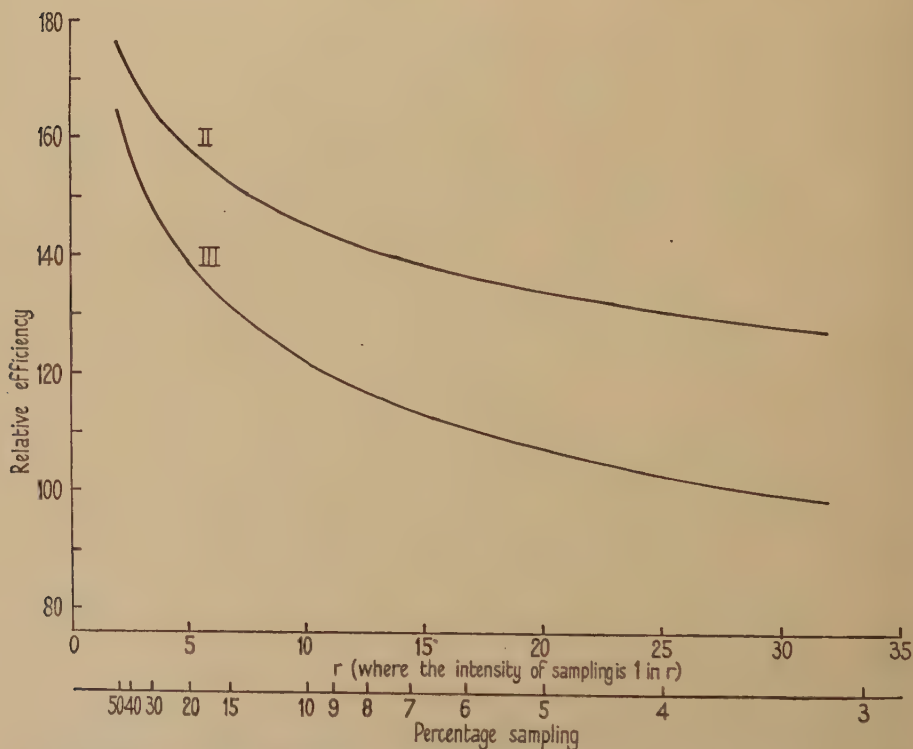


FIG. 5. Blacks Mountain: Efficiency of systematic sampling, IV, relative to stratified random, II and III, at different intensities of sampling. (See page 85 of text.) Upper curve: IV relative to II; lower curve: IV relative to III.

give variances corresponding to different sampling intensities. In this way the intensity of sampling required with any of the procedures I, II, III in order to give the same precisions as a systematic sampling of specified intensity is assessed. Figs. 6 and 7 show the results for the two forests. The pairs of curves for II and III are almost identical, a remarkable agreement; for unrestricted random

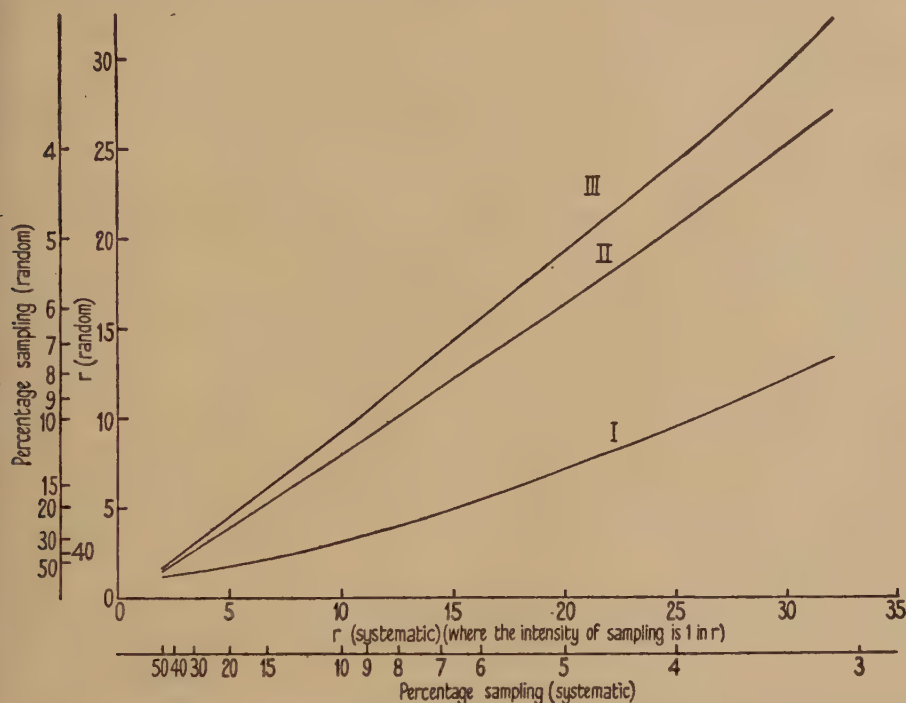


FIG. 6. Mount Stuart: Sampling intensity for random selection, I, II, and III, necessary to give same precision as a specified intensity with systematic selection, IV. (See text.) Lower curve: I relative to IV; middle curve: II relative to IV; upper curve: III relative to IV.

sampling, the Blacks Mountain curve reflects the lesser gain from stratification noted previously, by demanding an increase in sampling intensity less drastic than for Mount Stuart.

For comparison with results from other sets of data, the sampling errors per strip may conveniently be expressed as percentages of mean strip yield. The adjustment for finite sampling, represented by the factor $(1 - 1/r)$ in equation (4), should be introduced at this stage, so that the percentage standard error per strip is taken as:

$$\left. \begin{aligned} \text{percentage S.E. per strip} &= \frac{100S\sqrt{(1-1/r)}}{1025.5} \text{ for Mount Stuart} \\ \text{and percentage S.E. per strip} &= \frac{100S\sqrt{(1-1/r)}}{326.6} \text{ for Blacks Mountain.} \end{aligned} \right\} \quad (12)$$

Division of this quantity by $\sqrt{n}$ then gives the percentage standard error of the

sample mean, in accordance with equation (4), but for comparative purposes equation (12) is the better form. In Figs. 8 and 9 percentage errors for each of the four sampling procedures are plotted against r . As is to be expected, the values for unrestricted random sampling are considerably lower for Blacks Mountain than for Mount Stuart, but otherwise the two diagrams agree well.

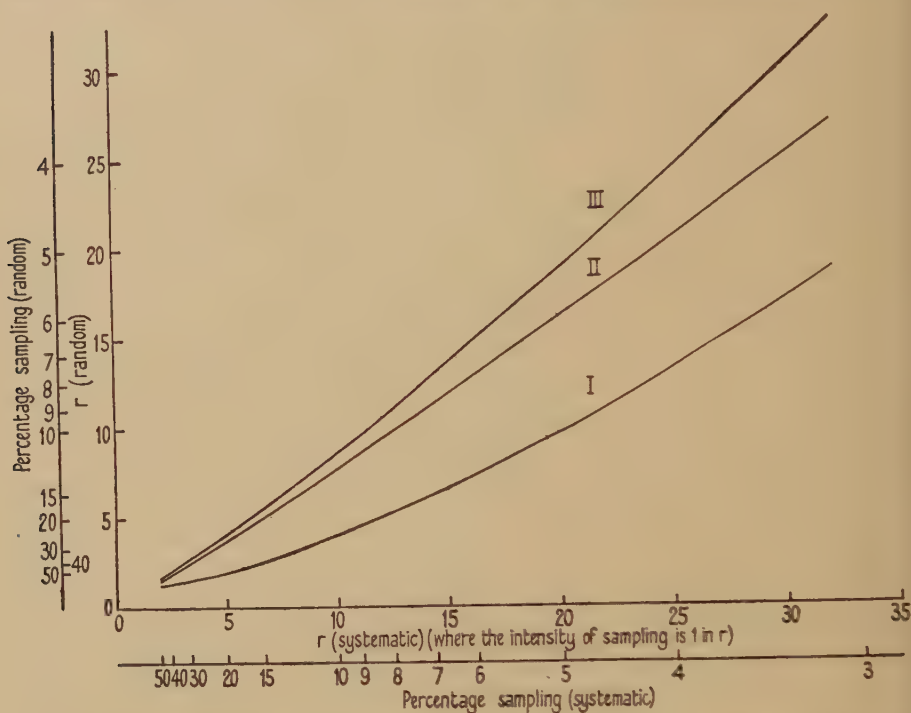


FIG. 7. Blacks Mountain: Sampling intensity for random selection, I, II, and III, necessary to give same precision as a specified intensity with systematic selection, IV. (See page 87 of text.) Lower curve: I relative to IV; middle curve: II relative to IV; upper curve: III relative to IV.

Griffith [1945c (8)] has discussed the limits of error of sampling estimates for Mount Stuart obtained by various sampling procedures. The results shown in Fig. 8 can be used to give similar limits for sampling of the type considered in this paper. For example, Fig. 8 shows a 1 in 10 systematic sample to have a standard error per strip of 14.1 per cent.; such a sample for Mount Stuart would consist of 16 strips, whence

$$\text{Percentage error of mean} = 14.1/\sqrt{16} = 3.52.$$

The limits of error for probabilities of 0.05 and 0.01 are obtained by multiplication of this figure by the normal deviates corresponding to these probabilities, 1.96 and 2.58. The result may be interpreted as a statement that an estimate for Mount Stuart based on a single 1 in 10 systematic sample is unlikely to deviate from the truth by more than 6.9 per cent., and very unlikely to deviate by more than 9.1 per cent. A selection of results of this kind is summarized in Table III.

In the previous paper [Finney, 1948 (5)] Griffith's estimations of error have been criticized. For a systematic sample he based his error either on a sum of squares of deviations of strip values about their mean, or on use of the many recording units ($1\frac{1}{2}$ -acre 'plots') within strips as though they were independently selected sampling units. For reasons which have been stated previously, if the

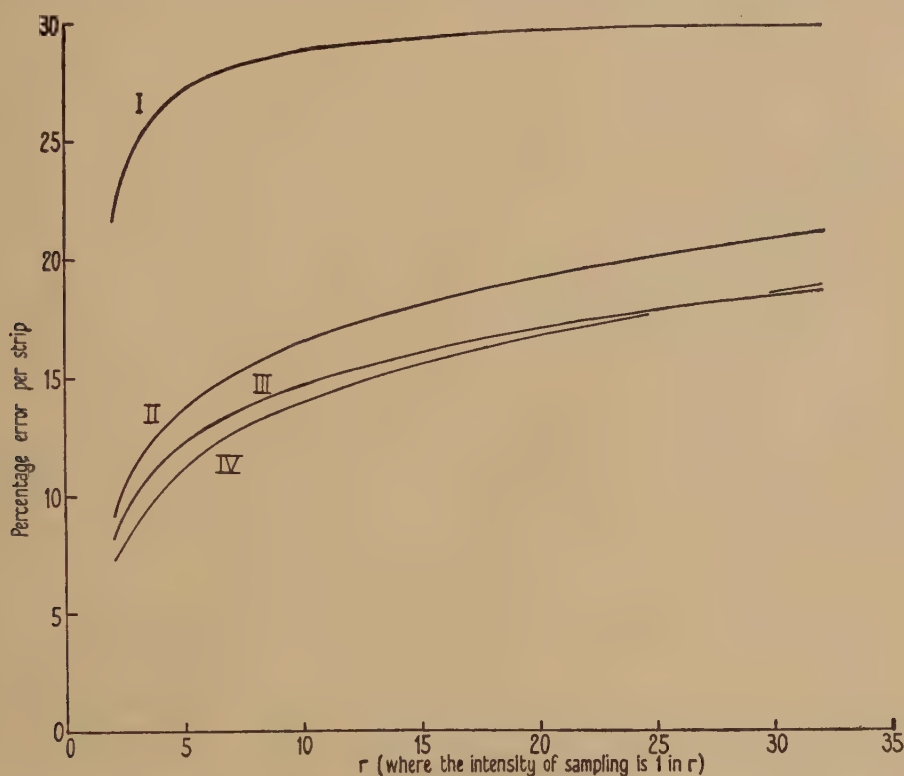


FIG. 8. Mount Stuart: Percentage error per strip for four sampling procedures, I, II, III (all random), and IV (systematic). (See page 88 of text.)

TABLE III. *Percentage limits of error for Mount Stuart*

Sampling intensity	<i>I in 5</i>		<i>I in 10</i>		<i>I in 20</i>	
	0.05	0.01	0.05	0.01	0.05	0.01
<i>Sampling method:</i>						
Unrestricted random (I) . . .	9.4	12.4	14.2	18.6	20.6	27.1
Stratified random (II) . . .	4.8	6.3	8.1	10.7	13.4	17.6
Stratified random (III) . . .	4.3	5.6	7.3	9.5	11.9	15.7
Systematic (IV)	4.0	5.2	6.9	9.1	11.7	15.4

variation in volume per unit area follows some systematic trends over the forest, his first method would usually overestimate the sampling error because of its use of variation between strips spaced as far apart as possible; the artificial example

given in Section 3 illustrates this effect in extreme form. His second method, on the other hand, might seriously underestimate the true error because of correlation between plots of the same strip. Indeed, as Langsaeter [1932 (20)] has pointed out, by subdivision of the strips into small enough units, the 'standard error' so assessed could be made arbitrarily small. Griffith's Table VI¹ gives

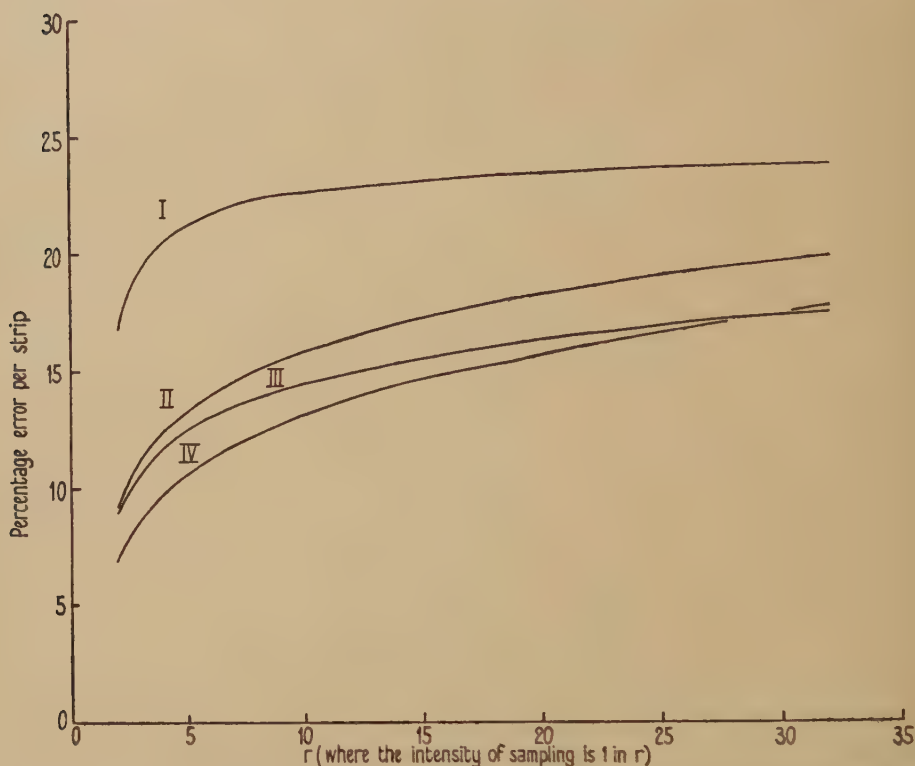


FIG. 9. Blacks Mountain: Percentage error per strip for four sampling procedures, I, II, III (all random), and IV (systematic). (See page 88 of text.)

12 per cent. and 16 per cent. as limits of error for 1 in 10 systematic sampling calculated from variation between strips, 4 per cent. and 6 per cent. as limits calculated from variation between the ultimate recording units, and intermediate figures if larger subdivisions of strips are used. The first pair of figures is unfair to systematic sampling, the second clearly exaggerates its precision, by comparison with the limits of 6.9 per cent. and 9.1 per cent. shown in Table III. Griffith later gives 8 per cent. and 11 per cent. as the two limits for a 1 in 20 systematic sample, presumably again calculated from recording units, as compared with the unbiased 11.7 per cent. and 15.4 per cent. in Table III.

Griffith has compared his figures for systematic sampling with similar figures

¹ Griffith's use of the words 'accuracy' and 'precision' does not agree exactly with the standard practice in statistical science [Finney, 1948 (5)], and care is needed in order to avoid confusion.

for random sampling, but scarcely allows the latter a fair chance since he considers only unrestricted random sampling. His correct analysis, based on strip means though apparently using only a single sample instead of an average over all possible samples, shows fiducial limits for 1 in 10 sampling at 13 per cent. (probability 0.05) or 18 per cent. (probability 0.01) from the estimated mean; these agree well with the 14.2 per cent. and 18.6 per cent. in Table III. For the Mount Stuart data, however, stratification has been shown to improve the precision of random sampling very considerably. With a sampling intensity of 1 in 5 or less (intensive sampling is unlikely to be of practical importance), the extreme form of stratification, having small blocks and only one sampled unit per block, may be seen from Table III to be almost as good as systematic sampling in respect of the limits of error in estimation. This is perhaps chiefly of theoretical interest, as indicating that the gain in precision attributed to systematic selection arises primarily from the restriction to small blocks; Method III has little practical advantage over Method IV, because it also fails to provide its own estimate of error. More important is the fact that even the larger blocks of Method II are sufficient to remove much of the variation found with Method I, and the resulting limits of error are not much wider than for Methods III and IV, with the advantage that assessment of error from a single sample is possible. A rough statement of the results shown in Table III would be that a 1 in 5 sampling of the 160 strips of Mount Stuart, by any of the Methods II, III, and IV, is almost certain to give an estimate within 5 per cent. of the truth, a 1 in 10 sampling to give an estimate within 10 per cent. of the truth, and a 1 in 20 sampling within 15 per cent. of the truth.

The results shown as Fig. 9 have been used in the construction of Table IV, which is analogous to Table III but relates to the sampling of the 288 strips of Blacks Mountain. Sampling fractions of 1 in 8, 1 in 16, and 1 in 32 have been chosen for comparison, because they fit conveniently into the total of 288 and also because they give practically the same numbers of strips per sample as did the sampling fractions compared for Mount Stuart. Table IV, indeed, agrees very closely with Table III, except that again unrestricted random sampling is seen to be relatively less imprecise than for Mount Stuart. Once more the increase in precision with systematic sampling is sufficient only to effect a slight narrowing of the limits of error, as compared with the two forms of a stratified random sampling.

TABLE IV. *Percentage limits of error for Blacks Mountain*

Sampling intensity . .		1 in 8		1 in 16		1 in 32	
Probability of error . .		0.05	0.01	0.05	0.01	0.05	0.01
<i>Sampling method:</i>							
Unrestricted random (I) . .		7.3	9.5	10.6	14.0	15.3	20.1
Stratified random (II) . .		4.9	6.4	8.0	10.6	12.8	16.8
Stratified random (III) . .		4.5	6.0	7.3	9.5	11.3	14.9
Systematic (IV) . .		4.0	5.3	6.8	9.0	11.4	15.0

Griffith also discussed estimation from an unrestricted random sample of $1\frac{1}{2}$ -acre 'plots' or recording units. For a 1 in 10 sample, he found limits of error at 6 and 8 per cent., corresponding to probabilities of 0.05 and 0.01 respectively. He concluded that the method is no more precise than a systematic sample of strips and, since it is also 'not usually practicable in forest work as it is too expensive to carry out', he dismissed it from further consideration. No doubt enumeration of a sample consisting of isolated small units would be impracticable in tropical forest, but under the easier sampling conditions of a temperate climate such a method might be valuable; its potentialities in respect of precision have yet to be fully explored.¹ Two-dimensional stratification should be as effective in reducing the sampling error of an estimate as was the one-dimensional stratification in strip sampling, and a systematic grid of units should also give results of much higher precision.

In his discussion of the Blacks Mountain data Hasel [1938 (18)] was largely concerned with sampling units other than strips, either with the small $2\frac{1}{2}$ -acre recording units or with some combination of these. Extension of the present methods to the investigation of samples in which the location of units is varied in two dimensions is simple in principle, but, like Mount Stuart, Hasel's data are scarcely sufficient for it to be satisfactory in practice. The analysis in this paper has therefore been restricted to strip sampling, and opportunities for numerical comparisons with Hasel's results are few. Hasel's Table 7 relates to 1 in 16 sampling, either at random within sections (blocks of 32) or systematic. His mean squares are derived from analyses in terms of recording units, and must therefore be multiplied by 8 in order to be comparable with Table II above. The agreement with the 1 in 16 entry for s_{II}^2 is then almost exact (for Hasel, $s_{II}^2 = 8 \times 381 = 3,050$), as it should be, but for s_{IV}^2 Hasel's figure is much smaller ($8 \times 189 = 1,510$), suggesting that his estimation based on totals for the 16 possible systematic samples is insufficiently reliable. Perhaps the simplest comparison is obtained by calculating the percentage standard error per strip from Hasel's figures; for stratified random sampling of type II this gives 16.4 per cent. (the smoothed value in Fig. 9 is 17.4 per cent.), and for systematic sampling, 11.5 per cent. (from Fig. 9, 14.8 per cent.). Hasel concluded that the variance for this systematic sampling was about half that for the stratified, but the conclusion seems to exaggerate the advantage of the systematic. Indeed, this result illustrates the point raised in Section 4 that the method usually adopted for calculating errors of systematic sampling from complete enumerations may allow too few degrees of freedom for the obtaining of a reliable figure; the combined analysis for many different sampling fractions presented above makes clear that the advantage for systematic sampling is very much less than his figures indicate. Mean squares for

¹ Griffith's recent condemnation [1947b (17)] of random sampling because 'in most tropical forests random sampling is either almost impossible physically, or so expensive as to be prohibitive for practical consideration' is perhaps intended to refer only to samples requiring the enumeration of isolated small plots. Even in tropical forest there can scarcely be much difference in cost or physical difficulty between a systematic sample of strips and an equal number of complete strips selected in accordance with a stratified random scheme.

stratified sampling of Type II at intensities of 1 in 16 and 1 in 8 and for unrestricted random sampling of 1 in 32 are shown in Hasel's Table 9; these are identical with the empirical, unsmoothed values of the present paper, except for the factor of 8 already mentioned.

7. DISCUSSION AND CONCLUSIONS.

To the question 'What is the best method of sampling a certain forest?' there could be no simple answer, even if the results of a complete enumeration were already available; still less can the answer be simple when it must be based only on previous experience of other forests. The word 'best' needs to be more exactly defined. According to Griffith [1945c (8)], 'In America, with temperate forests consisting of very few species and with fairly regular stands where fertility gradients tend to be irregular and difficult to determine without very intensive work, it has sometimes been found that random sampling gives considerably better results than systematic sampling.' If 'better' is here intended to relate to the true precision of the sample, the statement seems unlikely to be correct. In a forest for which the timber volumes on individual sampling units were distributed entirely at random, all sampling procedures at a given intensity, whether unrestricted or stratified random, or systematic, would lead to estimates with the same precision. Any tendency for the distribution of volumes to have a systematic pattern of variation over the area will in general result in stratified random selection giving a more precise estimate than unrestricted random, and systematic selection more precise than stratified random. If the pattern happened to have periodic variations with a period the same as the interval between units of a systematic sample, the precision of systematic sampling might be less than that of random [Finney, 1948 (5)], but in forest sampling this situation will rarely be encountered. The type of variation which occurs in forests is illustrated by Fig. 10, which shows the mean volume per acre for each of the 160 strips of Mount Stuart. Neighbouring strips are undoubtedly correlated and, as has been stated in Section 5, there is a marked trend from east to west, but there is no regular periodicity to upset the precision of systematic sampling.

In practice, choice of a sampling procedure must rest upon a compromise between high precision of estimation, the desirability of being able to assess that precision from the records of a single sample, and convenience and practicability in the field. The best procedure must therefore be to some extent a matter of opinion, for it depends upon the relative importance which the investigator attaches to these factors. Analyses such as those of Griffith and Hasel or of the present paper can help him only to the extent of indicating how variants in procedure may be expected to affect the precision. The conclusions from the Mount Stuart and Blacks Mountain data, though obviously requiring confirmation from similar analyses of other complete enumerations, are in sufficiently close agreement to suggest replies to some of the more important questions.

If a single sample is required to furnish its own estimate of the sampling error of the mean, by orthodox statistical processes, its sampling units must be selected at random, either unrestrictedly or stratified in such a way that at least two are

selected from each block. General argument and the specific evidence presented in Sections 5, 6 indicate the desirability of stratification, preferably using the smallest permissible blocks so that only two units have to be selected from each. In this way, maximum precision is obtained from a specified sampling intensity, or a specified precision attained with the smallest sample, subject to the limitation that internal evidence shall provide an assessment of error.

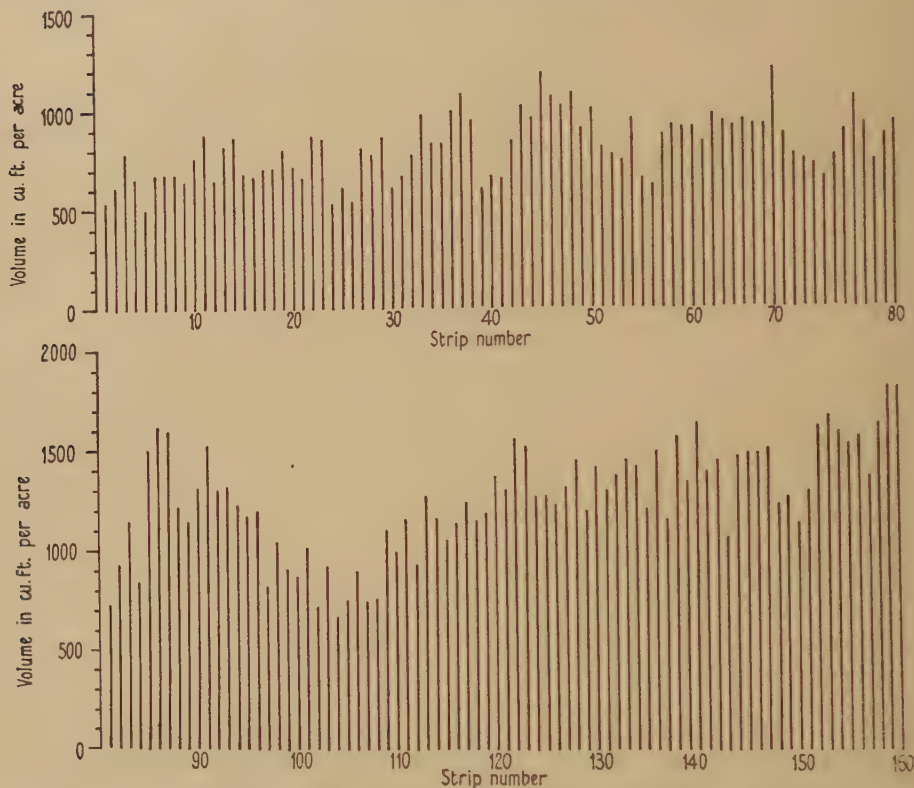


FIG. 10. Diagram to show the mean volume of timber per acre for each of the 160 strips of Mount Stuart.

That either the extreme form of stratification, in which only one strip is selected at random from blocks of the smallest possible size, or systematic sampling will usually improve the precision cannot be denied, but adoption of these procedures precludes an assessment of error from a single sample. The investigator may rightly consider that, in some circumstances, the gain in precision and the greater convenience of the systematic sample outweigh its disadvantages; the extreme stratification, however, is perhaps of theoretical interest only, for it is likely to be less convenient and no more precise than systematic selection, yet is no better for assessment of error. The data studied in this paper suggest that the improvement in precision associated with systematic sampling may be less great than is imagined by those who, well aware of the existence of systematic patterns of variation in the

forests they know, understand less well the exact influence of the pattern on sampling precision. Figs. 6 and 7 agree in showing that no very great increase in sampling intensity is required in order that a stratified random sample may give a precision equal to that of a systematic sample at a specified intensity. Tables III and IV express the same point still more forcibly, by showing the limits of error for stratified sampling to be little wider than those for systematic at intensities of sampling of the order likely to be used. For more intensive sampling the differences would be greater.

These tables amply justify Griffith's contention that in forest surveys 100 per cent. enumerations are not essential. Undoubtedly sampling estimates of timber volume can be made sufficiently reliable for practical purposes. In this way a great saving in time and cost of surveys can be effected; often the improved quality of the data arising from the care that can be given to the enumeration of a small sample will be more valuable than the apparent completeness of hurriedly executed measurements and records in a complete enumeration. Yates [1946 (29)] has stated: 'Nevertheless, I feel certain that in extensive area surveys systematic line or grid sampling is preferable to random sampling. The additional work required to investigate the accuracy attained will be more than compensated for by the saving in work in the survey itself.' Against this opinion the evidence of the present paper suggests that increase in precision alone is seldom sufficient reason for the adoption of systematic sampling, and that unless there is also a strong argument on the grounds of practicability a stratified random selection should be preferred. This argument would be destroyed if a method of assessing precision for a unique systematic sample could be developed, but at present such an assessment seems impossible, rather than merely requiring 'additional work'.

A paper frequently quoted in discussions of systematic strip sampling is that of Osborne [1942 (25)]. This has not been considered in detail here because it relates to cover-type areas, not to timber volumes, and also because the data were not available for analysis by the present methods. Using data from an enumeration of 600 out of a total of 960 strips, Osborne reports systematic 1 in 32 sampling to be more precise than stratified sampling in blocks of 64, taking two strips from each block, for the purpose of estimating areas of several different cover-types. He did not examine the extreme (Type III) stratification. The increase in precision attributable to systematic selection appears to be greater than has been found for Mount Stuart and Blacks Mountain, but, as it has been calculated for only one sampling intensity, no very satisfactory conclusion can be drawn. A detailed analysis of Osborne's data, using many different sampling intensities, would be of considerable interest as throwing light upon the relative merits of different area sampling procedures for the estimation of another kind of measurement.

The choice of sampling procedure would become much easier if some method of deriving an estimate of error from a systematic sample could be devised. As has been said in Section 1, such a method must involve additional assumptions about the pattern of variation in a forest. The example in Section 3 shows how

misleading may be a supposed assessment of error from a sum of squares between sampling units of a systematic sample. Scandinavian writers, notably Langsaeter [1932 (20)], Näslund [1939 (23)], and Östlind [1932 (26)], have suggested calculating an error from differences between successive units in a systematic sample, or from second-order differences of the form $(x_1 - 2x_2 + x_3)$, $(x_2 - 2x_3 + x_4)$, &c. (where $x_1, x_2, x_3, \dots$ represent volumes for successive strips of the sample). The justification for a method of this kind must be empirical rather than theoretical, and more extensive verification than has yet been made is needed in order to show that, for completely enumerated areas, sampling errors so calculated are unbiased and tolerably reliable estimates of the true errors of systematic sampling. Like the tentative suggestions of Yates [1946 (29)], these must be tested thoroughly on different collections of complete enumeration data before they can be trusted as indicating the error of future unique systematic samples.

This paper is concerned only with the comparison of random and systematic sampling schemes. The reader should remember that the size and shape of blocks and sampling units, and their orientation relative to known or suspected fertility gradients, may also be important factors influencing the precision of a sample estimate. These have been discussed in the earlier paper [Finney, 1948 (5)]. The need for mapping the area may be another consideration in determining the choice of sampling procedure, and a compromise will then have to be sought between the optimal conditions for total volume estimation and for mapping. Those who have had experience of enumeration in the field will scarcely require a statistician's warning of the need for a comprehensive system of checking at all stages of the work; independent duplicate enumeration of certain sampling units should be arranged as an essential part of the routine in the collection of data, and the statistical analysis should be subjected to checks sufficient to ensure that good data are not obscured by careless arithmetic.

8. SUMMARY.

Data from two completely enumerated forest areas, one of mixed tropical deciduous type from Madras and the other of pure pine from California, have been used in a comparison of different strip-sampling procedures. The variances for unrestricted random strip sampling, stratified random sampling taking either two strips or one strip from each block, and systematic sampling, at different sampling intensities between 1 in 2 and 1 in 32, have been calculated. In Section 4 a full description of the methods of obtaining the variances has been given, for the benefit of those who may wish to make similar analyses of other data.

The results show clearly that sampling for the estimation of volumes of standing timber can give a figure sufficiently reliable for practical purposes without requiring that an unreasonably large sample be taken. In Griffith's words 'Intensive and expensive 100 per cent. enumerations are NOT necessary in order to obtain a reasonable estimate of the growing stock.' A stratified or systematic sample consisting of 30-35 strips and representing about 1 strip in 5 or 1 in 8 of the whole forest, for the two areas discussed, was fairly certain to give an estimate within 5 per cent. of the truth (in one forest the strips were 3 chains in width and

averaged 45 acres in area, in the other they were 2.5 chains in width and 20 acres in area). Sampling at half this intensity would have given estimates within 10 per cent. of the truth, sampling at one-quarter this intensity within 15 per cent. of the truth. Though these conclusions are based on two forests only, the remarkably close agreement between the two encourages the belief that they may be regarded at least as an indication for other areas.

As was expected, unrestricted random sampling showed much larger sampling errors than did the other three types. Detailed comparisons reported in Section 6 may be summarized by the statement that systematic sampling proved more precise than either form of stratification, but that the consequent narrowing of the limits of error is scarcely sufficient to justify a general recommendation that systematic sampling be always used. The data examined suggest that, except when very little importance is attached to knowledge of the sampling error, a stratified random selection of two strips per block, even though less precise, may often be preferable to a systematic selection of strips from which no assessment of sampling error can be made. The situation will be changed if a sound method of estimating the error of a systematic sample can be found; until then, an investigator should adopt systematic sampling only after careful consideration of its implications.

This paper relates only to the one-dimensional sampling problem, using enumeration by strips. In types of forest for which enumeration of isolated smaller recording units is practicable, greater precision for a given intensity of sampling is to be expected if the restriction to sampling by complete strips is removed. Both stratification and systematic selection should lead to great increases in precision by comparison with unrestricted random selection of units. If suitable data were available, the magnitudes of these increases in precision could be studied by extensions of the methods used here.

ACKNOWLEDGEMENTS.

I am deeply indebted to Dr. A. L. Griffith, lately Silviculturist to the Forest Research Institute, Dehra Dun, India, and to Mr. A. A. Hasel, Silviculturist to the California Forest and Range Experiment Station, for their generous assistance in supplying the data on which this paper is based. My thanks are also due to the President of the Forest Research Institute, Dehra Dun, India, for permitting the use of the Mount Stuart data. My debt to Dr. Griffith is increased by his part in a long correspondence relating to his data and publications, and by his patient explanation of my difficulties. I wish also to express my thanks to Dr. F. Yates, of Rothamsted Experimental Station, for suggestions on the method of analysis.

The views I express on the vexed question: 'random or systematic sampling?' are my own. No acknowledgement to those who have helped to make this paper possible should be thought to imply that they share the responsibility for the conclusions I draw. Indeed my thanks to Dr. Griffith and Mr. Hasel are the greater because of their willingness to let me use their data in a discussion of controversial questions, where I may express opinions at variance with those that they have formed from the same data.

LITERATURE REFERENCES.

- (1) Brasnett, N. V. (1946): 'The Efficiency of Enumerations: A Review.' *Empire Forestry Review*, xxv. 42-6.
- (2) Cochran, W. G. (1939): 'The Use of the Analysis of Variance in Enumeration by Sampling.' *Journal of the American Statistical Association*, xxxiv. 492-510.
- (3) — (1946): 'Relative Accuracy of Systematic and Stratified Random Samples for a Certain Class of Populations.' *Annals of Mathematical Statistics*, xvii. 164-77.
- (4) Deming, W. E. (1947): *A Brief Statement on the Uses of Sampling in Censuses of Population, Agriculture, Public Health, and Commerce*. United Nations Sub-Commission on Statistical Sampling.
- (5) Finney, D. J. (1948): 'Volume Estimation of Standing Timber by Sampling.' *Forestry*, xxi. 2, 179-203.
- (6) Griffith, A. L. (1945a): *The Efficiency of Enumerations*. I. *The Problem*. Forest Research Institute, Dehra Dun, Indian Forest Leaflet, no. 83.
- (7) — (1945b): *The Efficiency of Enumerations*. II. *Madras Tropical Wet Evergreen Forest*. III. *Typical Calculations*. Ibid., no. 84.
- (8) — (1945c): *The Efficiency of Enumerations*. IV. *Madras Moist Mixed Deciduous Forest*. Ibid., no. 85.
- (9) — (1945d): *The Efficiency of Enumerations*. V. *Upper Assam Tropical Evergreen Forest*. VI. *Typical Calculations*. Ibid., no. 86.
- (10) — (1945e): *The Efficiency of Enumerations*. VII. *The Distribution of the Volume Figures*. Ibid., no. 87.
- (11) — (1945f): *The Efficiency of Enumerations*. VIII. *Chir (Pinus longifolia) Forest in the Punjab and United Provinces*. Ibid., no. 88.
- (12) — (1945g): *The Efficiency of Enumerations*. IX. *The Distribution of the Volume Figures (contd.)*. Ibid., no. 89.
- (13) — (1946a): *The Efficiency of Enumerations*. X. *Hill Sal (Shorea robusta) Forest in the United Provinces*. Ibid., no. 90.
- (14) — (1946b): *The Efficiency of Enumerations*. XI. *The Distribution of the Volume Figures (contd.)*. Ibid., no. 91.
- (15) — (1946c): *The Efficiency of Enumerations*. XII. *One Species in a Mixed Forest (Teak in a Madras Moist Deciduous Forest)*. XIII. *Confirmation of the Chir (Pinus longifolia) and Sal (Shorea robusta) Data*. XIV. *Summary of Indications*. Ibid., no. 93.
- (16) — (1947a): 'The Efficiency of Enumerations.' *Indian Forester*, lxxiii. 102-7.
- (17) — (1947b): 'The Efficiency of Enumerations.' *Empire Forestry Review*, xxvi. 105.
- (18) Hasel, A. A. (1938): 'Sampling Error in Timber Surveys.' *Journal of Agricultural Research*, lvii. 713-36.
- (19) — (1942): 'Estimation of Volume in Timber Stands by Strip Sampling.' *Annals of Mathematical Statistics*, xiii. 179-206.
- (20) Langsaeter, A. (1932): 'Nøiaktigheten ved linjetaksering av skog. I. Bestemmelse av treantall og dimensjonsfordeling' ['Accuracy in Strip Survey of Forests. I. Determinations of the Number of Trees and the Distribution of Dimensions']. *Meddelelser fra det Norske Skogforsøksvesen*, iv. 431-564.
- (21) Madow, W. G., and Madow, L. (1944): 'On the Theory of Systematic Sampling, I.' *Annals of Mathematical Statistics*, xv. 1-24.
- (22) Matérn, B. (1947): 'Metoder att uppskatta noggrannheten vid linje- och provytetaxering' ['Methods of Estimating the Accuracy of Line and Sample Plot Surveys']. *Meddelanden från Statens Skogsförsöksanstalt*, xxxvi. 1-138.
- (23) Näslund, M. (1939): 'Om medelfelets härledning vid linje- och provytetaxering' ['On computing the Standard Errors in Line and Sample Plot Surveying']. Ibid., xxxi. 301-44.
- (24) Neyman, J. S. (1934): 'On the Two Different Aspects of the Representative Method: The Method of Stratified Sampling and the Method of Purposive Selection.' *Journal of the Royal Statistical Society*, xcvi. 558-625.

- (25) Osborne, J. G. (1942): 'Sampling Errors of Systematic and Random Surveys of Cover Type Areas.' *Journal of the American Statistical Association*, xxxvii. 256-64.
- (26) Östlind, J. (1932): 'Erofordelig taxeringsprocent vid linjetaxering av skog' ['The Requisite Survey Percentage when Line-surveying a Forest']. *Svenska Skogsvårdsföreningens Tidskrift*, xxx. 417-514.
- (27) Schumacher, F. X., and Chapman, R. A. (1942): *Sampling Methods in Forestry and Range Management*. Duke University Press, Durham, North Carolina.
- (28) Smith, H. F. (1938): 'An Empirical Law describing Heterogeneity in the Yield of Agricultural Crops.' *Journal of Agricultural Science*, xxviii. 1-23.
- (29) Yates, F. (1946): 'A Review of Recent Statistical Developments in Sampling and Sampling Surveys.' *Journal of the Royal Statistical Society*, cix. 12-43.

LOGGING IN BRITISH COLUMBIA

By JOHN T. SMITH

IN the autumn of 1947 the writer went to Canada as a member of a Timber Trade Delegation from the United Kingdom for the particular purpose of inspecting the timber resources and methods of production in British Columbia. Some impressions gained in the course of this tour may be useful to foresters.

For a country not very far advanced in the practice of scientific silviculture, Canada appears to be rich in knowledge of her resources. The Forest Service keeps an inventory of the resources of the Province and publishes full details periodically. Government departments and lumber trade alike have valuable statistics for those who require information, and they do not hesitate to provide it generously on request. The list of references at the end of this article includes some of the more important sources of information [(2), (4)—(7), (9), (10)].

A home timber merchant from Great Britain is pleased to find that there are no State saw-mills in Canada nor are there any logging operations conducted by the State. A very flexible system of leases and annual licences covers the needs of operations differing widely in character and extent. The time for removal of timber is generous in the larger concessions; and even the smaller sales of standing timber are for 1 to 5 years, giving ample time to cover changes in market conditions and ensure security to the smaller operators.

Eleven per cent. of the merchantable timber in British Columbia is privately owned. The remainder consists of unalienated Crown timber (57 per cent.) and cutting rights licensed on Crown lands (32 per cent.). Sales of timber by the Crown are by public advertisement. Sealed tenders are invited (with several weeks' notice) for specified quantities of trees, the contents being given and the time for removal indicated, usually 2 to 5 years. (In eastern Canada sales are sometimes by public auction. One such sale, advertised in a Winnipeg paper, covered the right to cut about $3\frac{1}{2}$ million feet, board measure (about 300,000 cu. ft.), of timber. The lots were offered for sale by public auction at an upset price of 4 dollars per 1,000 feet, board measure (83 cu. ft.), for 'Spruce, Jack Pine, and Birch' lumber, all other products to go to the purchaser at the regulation rates. Five years were allowed for removal. Each bidder was required to deposit with the officer conducting the sale 2,500 dollars in cash, bank draft, or accepted cheque, before being allowed to bid. The purchaser was required to furnish within 30 days a satisfactory bond for 8,000 dollars.)

The Forest Act (Consolidation 1945), British Columbia (3), contains useful information regarding the assessment of private timber land, the sale of cutting rights for unalienated timber (Section 17), the measurement and grading of timber (Section 77), the marking of logs (Section 82), and fire control (Sections 117 and 122). All timber must be scaled (measured) by a scaler licensed by the Forest Service after the tree has been felled but before it is sawn up.

The relations between State and timber trade appear to be very friendly. This is borne out by recent legislation in British Columbia, where a Bill, No. 7 (1), which made numerous amendments to the Forest Act became law on 3rd April 1947. The Bill provided for the establishment of 'Management License Areas'. Section 12, Sub-section (2) of the Bill reads as follows:

'The minister may enter into an agreement, to be described as a forest management license, with any person for the management of Crown lands specified in the agreement and reserved to the sole use of the licensee for the purpose of growing continuously and perpetually successive crops of forest products to be harvested in approximately equal annual or periodic cuts adjusted to the sustained yield capacity of the lands in the area covered by the license, or may enter into an agreement, to be known as a forest management license, with the owner of other tenures to combine such other tenures and Crown forest lands into a single unit reserved by mutual consent and contract to the sole use of the licensee for the like purpose.'

In short this means that British Columbia has provided for the establishment of sustained yield management.

Sustained yield management and the whole future of the forests of British Columbia are discussed very thoroughly in a notable report (9) which appeared at the end of 1945, being the findings of a one-man Commission under the Public Inquiries Act. The Commissioner was the Hon. Gordon McG. Sloan, Chief Justice of British Columbia, and the report is entitled *The Forest Resources of British Columbia*. It is the result of over 100 days of session, the hearing of some 300 witnesses and the examination of some 12,000 pages of evidence. Its findings and recommendations repay careful study. It is predicted that European exporting countries will be competitors for Canadian markets, particularly when Canadian production is drawn from second-growth forests. A figure of 90 per cent. accessibility for the coast forest areas is taken as a sufficiently close approximation upon which to base future policy.

Two new clauses in the Forest Act are specially significant:

Section 12, Sub-section (17) reads:

'A licensee shall employ one fully qualified forester, who shall be a graduate of a school of forestry approved for the purpose by the Minister, and as many additional similarly qualified foresters as the licensee or the Minister may deem necessary.'

Subsequent clauses provide for exemption from taxation, joint employment of a forester, &c., according to the areas contemplated.

Section 12, Sub-section (23) says:

'Such improvements on a license area as are designed to facilitate the management and operation of, and the growing and harvesting of wood on, any lands in the license area shall be exempt from taxes under the "Taxation Act".'

The demand for plywood unfortunately means the extinction, on the west coast at least, of the heavier timber logs within the next 25 years. The present cuts are in forests of from 250 to 350 years of age or more.

A development in recent years is what is known as patch-logging. Now that home timber merchants in Great Britain have begun afforestation work and have

already planted hundreds of acres for others as well as for themselves, it may be of interest to discuss this method in detail.

One of the principal lumber firms in British Columbia has been carrying out the method of patch-logging for a number of years on Vancouver Island. In the words of the President of the Company

'The principle is to clear-cut patches of about 130 to 300 acres, each surrounded on 2 to 4 sides by mature timber which is not logged until a lapse of 5 to 8 years. The size of the patch depends on the topography, the type of logging machinery used and other considerations.'

From 1937 to 1942 his company had regenerated 9,240 acres previously patch-logged by them. By 1944 the whole area had been 49 per cent. satisfactorily restocked according to Forest Branch standards. Seeding will continue for several years and the area would have been as much as 64 per cent. stocked but for a serious forest fire which destroyed 1,500 acres of young trees. He suggests that if the Forest Branch would continue to furnish young trees free (as apparently they now do) and supervise planting methods to achieve good results, it would be in the public interest that blanks should be planted while the logging organization is in the neighbourhood. He further claims that filling the blanks costs $3\frac{1}{2}$ dollars per acre for the area logged, compared with expenditure by the Forest Service of twice to five times that amount if the work is postponed until afterwards, involving housing of men and other work which could have been avoided. He recommends that, subject to penalties for non-performance, the logger should be responsible for the cost of planting blanks up to about 8 years after logging, to bring the restocking up to a standard accepted by the Forest Branch, say, 75 to 80 per cent. fully restocked. He assumes that the cost would be allowable as an operating expense. The benefits of patch-logging appear to outweigh the extra logging costs, the principal benefits being reduction of fire risk and loss, and reduced costs of erosion and soil destruction. One additional great benefit would be that the larger area opened up by the extraction road systems would give easier access to the remaining stands for selection logging for special markets.

Canada loses by fire every 2 years about 5,000,000 acres of woods, an area equal to the total forest which Great Britain hopes to establish in the next 50 years. The resources of the State Forest Departments are to a large extent devoted to fire control. If the losses could be substantially reduced, and this is difficult owing to the low density of population, there would be little need for afforestation schemes as known in Great Britain. Nature would do most of the work. Incidentally, a point of interest to Great Britain is the controversy between foresters in Canada as to the wisdom of burning slash after felling operations. To do so lessens the fire hazard but may damage the soil and defer regeneration.

The evidence taken by the Sloan Commission in regard to the fire hazard and other consequences of slash-burning reveals much conflict of opinion. The new evidence does not, however, improve on the advice given in April 1944 in Bulletin No. 10, issued by the Oregon State Board of Forestry (8), which sums up the matter in these words: 'Failure to burn, where the facts indicate a need for burning, is not good forestry. It is equally poor forestry to burn unless the facts

clearly require it.' There are many other things in the Sloan Report of great interest to foresters, and it is obvious that some of the recommendations have already influenced the Forest Act. One amendment, suggested but not yet passed, is that the Forest Act should be broadened to permit the use of the cubic foot scale as well as the board-foot system of measurement.

It is reckoned that western hemlock (*Tsuga heterophylla*) may constitute as much as 75 per cent. of the next crop on land which previously carried mostly Douglas fir (*Pseudotsuga taxifolia*). The predominance of one species may invite insect epidemics but otherwise hemlock seems to be welcomed, as its growth per acre per annum is 40 per cent. higher than that of fir on similar sites. In any case Canadian lumbermen are now taking infinitely more trouble to produce more highly graded timber from hemlock, which after kiln drying is advertised as tasteless, odourless, and strong.

Logging is spectacular in the west of Canada, where the trees are large and relatively accessible to the coast. About 40 per cent. of the output is produced by independent logging companies without saw-mills and sold to the large saw-mill companies who do the rest of the logging on a big scale themselves. The equipment for extracting the heavier trees is diesel or steam skidders and railroads, with spur lines, working to the coast for rafting. Increasing use is being made of caterpillar tractors and road-haulage vehicles. Some of the road vehicles are also impressive, 50 tons of timber in one load being not uncommon. Instead of a railway, one operator had laid down a plank road (9 in. $\times$ 3 in. deals over heavy logs) for 15 miles into the forest. The track contained as much timber as would have been the output for a whole year for one trade portable mill in Great Britain.

Such heavy equipment precludes the possibility of extraction of smaller logs at the same time, and in places where a closer integration of saw-mill plants with pulp and fibre-board plants has not been possible much of the smaller timber is or has been abandoned. In one paper-mill visited, large-diameter logs of Sitka spruce (*Picea sitchensis*) from the Queen Charlotte Islands were peeled and quartered before being fed to the grinding machines. The output of this mill was of the order of 500 tons of paper per day (45 per cent. hemlock (*Tsuga heterophylla*), 45 per cent. Sitka spruce (*Picea sitchensis*), and 10 per cent. 'balsam fir' (probably *Abies grandis* or *Abies amabilis*)). There are still some paper companies who find that round logs are more suitable than slabs for certain grades of pulp, but a successful effort to make slabs suitable for pulping was seen in operation at one saw-mill on Vancouver Island. The slabs were previously regarded as waste but were now being fed mechanically at the rate of 150 linear feet per minute into a Sumner hydraulic slab barker, which is a compact fabricated steel outfit, comprising a box-like compartment. Inside this compartment the slabs pass through a series of shower-baths created by a stream of water pumped at 1,200 lb. per sq. in. through specially designed nozzles at 600 U.S. gallons per hour. Timber, clean and smooth and entirely free of bark, came out at the other end. It is claimed that the improvement of the product and the saving in wood with this outfit, over knives and the drum system, will soon repay the cost of

investment. The mill in question is particularly well placed in that the water required comes from a lake 5 miles away, through the company's own wood-stave pipe-line, the capacity of which is 20 million gallons per day. The initial demand of the saw-mill and pulp-mill is in the neighbourhood of 8 million gallons per day.

This is probably the place to mention the important experiment which the Forest Products Laboratories of Canada have been conducting since 1943 on the use of chemicals to aid in the removal of bark from timber intended for pulp-making. It is claimed that such a process will promote drying of the wood. So far the chemicals most effective have been water-soluble arsenic compounds, applied to the standing tree in spring and early summer, during the 'sap peeling' season. The trees tested have been white spruce (*Picea glauca*), black spruce (*Picea mariana*), balsam fir (*Abies balsamea*), jack pine (*Pinus banksiana*), and paper birch (*Betula papyrifera*). Western red cedar (*Thuja plicata*) for telegraph poles has been similarly treated also. The investigation is proceeding. It may be that in the end the cost of this method will be much less than the water process described in the preceding paragraph.

Canadians prove that it is much easier to handle logs in water than on land. In eastern Canada logs are towed in lakes and rivers for considerable distances, and on the west coast logs are sometimes towed several hundred miles in the sea to the saw-mills. From the moment the tree is felled, until it reaches the mill, it is handled mechanically.

Felling by mechanical saws is popular in western Canada. One timber company had 30 Burnett power-chain saws with Villiers motors. Each weighs 130 lb. complete and the horse-power is 9. A 30-inch-diameter tree can be felled in 3 minutes. The record is a 30-inch log in 8 seconds. One feller, with four cross-cutters, will cut 40,000 ft. board measure (3,000–3,500 cu. ft.) in 8 hours with this machine. The method is to make two undercuts on the side of the tree towards which it is to fall. The resulting wedge is axed out (the tool is part axe and part pick). A final cut is made on the opposite side of the tree, and without the assistance of metal wedges the tree falls easily in the exact direction required. One felled tree was examined by the delegates and found to be about 470 years old (Plate V). It had 217 feet of timber length and contained just over 1,200 cu. ft. With these heavy trees one disadvantage of using the power-saw is that for safety and other reasons the saw has to be held at breast height, involving the loss of a high stump containing much valuable timber. In many cases the high stump avoids a swelling towards the roots, and if the cut were made at ground level it would add appreciably to the diameter to be sawn.

In mountainous country extraction is by steam or diesel skidder, with skyline or high lead. (In the interior of British Columbia the use of skyline or high lead in thinning operations is prohibited.) Prior to the installation of these outfits there is a complete survey of the whole area. One lumberman explained that there were no ordnance sheets and often they had to make their own. Roads and railways and bridge-building are major forest engineering jobs at which the Canadian lumbermen excel.

In Canada very large sums of money are invested in plant, machinery, and

logging equipment. In pre-war years over 70,000 people were employed in Canada, in logging alone, and to-day the numbers have increased greatly.

One important firm in Vancouver Island (Messrs. Bloedel, Stewart & Welch, Ltd.) was kind enough to furnish the undernoted statistics of their Franklin River logging operations:

Annual production (one firm only)

62 to 132 million feet, board measure (5 to 11 million cu. ft.).

Average 90 million feet, board measure ($7\frac{1}{2}$ million cu. ft.).

Douglas fir (*Pseudotsuga taxifolia*), Cedar (*Thuya plicata*), Hemlock (*Tsuga heterophylla*),

Pine (*Pinus ponderosa*), Spruce (*Picea engelmannii*).

Annual usage.

1,800 acres of timber land.

10 miles of road.

Wire rope: 10 miles.

Explosives for road construction: 61 tons of 40 per cent. dynamite.

Lumber for construction and maintenance: 1,200,000 ft., board measure (100,000 cu. ft.).

Fuel oil: 43,500 barrels.

Organization.

Road construction.	.	.	.	36 men.
Road maintenance.	.	.	.	23 "
Falling and bucking (cross-cutting)	.	.	.	75 "
Yarding and loading	.	.	.	96 "
Rail haul	.	.	.	31 "
Booming and towing	.	.	.	10 "
Board and lodging.	.	.	.	43 "
Supervision	.	.	.	10 "
Fire prevention	.	.	.	5-30 men (seasonal work).
Forest engineering	.	.	.	5-10 " " "
Forestry	.	.	.	3-50 " " "

Equipment.

Road construction

- 1 $1\frac{1}{2}$ -yd. Northwest shovel.
- 1 1-yd. " "
- 2 D.8 caterpillar bulldozers.
- 1 500-c.f.m. Le Roi air compressor.
- 1 300-c.f.m. Holman " "
- 2 pile-drivers.
- 6 ballast cars.
- 6 flat cars.

Falling and bucking (cross-cutting).

- 30 Burnett power-saws (Villiers engine).

Yarding and loading.

- 1 $12\frac{1}{2}$ in. $\times$ 14 in. Lidgerwood lower skidder 2,100 ft. span.
- 1 $13\frac{1}{2}$ in. $\times$ 14 in. " " " 2,300 "
- 1 $13\frac{1}{2}$ in. $\times$ 14 in. Lidgerwood tree-rig skidder 2,300 "

1 12 in. × 14 in. Willamette slack line	1,600 ft. span.
1 275-h.p. Clyde slack line	1,400 "
1 150-h.p. Skagit slack line	1,200 "
1 100-ton locomotive crane	
1 rig-up machine.	

Railroad equipment and practice.

- 60 miles standard-gauge track, 56 to 80 lb. steel.
- 3.5 miles bridges, up to 110 ft. high.
- Minimum curvature, 200 ft. radius.
- Maximum grade, 7.5 per cent.
- 3 90-ton Pacific Coast Shay geared locomotives.
- 1 70-ton " " " " locomotive.
- 1 60-ton " " " " "
- 120 40-ton capacity logging cars, 45 ft. long, 10 ft. bunks.
- 4 60-ton capacity logging cars, 70 ft. long, 10 ft. bunks.
- 1 90-ton capacity equipment moving car.
- 6 10,000-gal. oil cars.
- 2 70-man speeders (for hauling crew).
- 2 20-man " " "

Booming and towing.

- 4 100-200-h.p. tugs.
- Booms are 70 ft. × 560 ft. and average 250,000 ft., board measure (20,000 cu. ft.).

Fire protection.

- 5 tank cars.
- 14 portable pumps.
- 9 miles of hose.
- 2 fire-tool cars.

The 90-ton locomotive hauls 12 empty cars, weighing 95 tons, up a 7½ per cent. grade at 10 miles per hour, or it hauls 24 loads of logs, weighing 300 tons, up a 1½ per cent. grade at the same speed.

The Timber Trade Delegation were taken over a considerable length of this private railway, and particularly over 2 miles which had produced a phenomenal average of 80,000 ft., board measure (6,000-7,000 cu. ft.) per acre of 275-year-old Douglas fir (*Pseudotsuga taxifolia*) and hemlock (*Tsuga heterophylla*). The area had been planted up with 750,000 Douglas fir seedlings immediately after being logged. Normally the lumbermen plant Douglas fir at the rate of 1,000 trees per acre, leaving nature to fill in the gaps, usually with western hemlock, a prolific seeder.

One logging camp visited had a normal crew of 400 men. The accommodation consisted of 58 eight-man bunk-houses and 52 family houses, each containing a living-room, kitchen, bathroom, and two bedrooms. They were equipped with electric power, hot and cold water, and a complete bathroom set, including either shower or tub. Most of the occupants equip their houses with refrigerators. In addition the camp contained a recreation hall, 40 feet × 80 feet; a recreation field, 400 feet by 400 feet; a central water system, electric power system, and

a central sewage system; stores, post office, school, &c.; all set down on an area which had been cleared of trees and was situated about 20 miles from the nearest town. The duration of this camp was stated to be 6 years. The dwelling-houses had neat gardens and were all timber constructed, with shingled roofs. They were superior to any of the prefabricated houses in Great Britain.

Some details are available of the largest steel tower Lidgerwood skidder used by this firm. It cost 105,000 dollars, completely equipped. The weight is 220 tons. The width is 14 feet and the length 46 feet. The height of spar is 105 feet. Powered by a 400-h.p. boiler with a pressure of 200 lb., the skidder has a range of almost half a mile radius, involving the use of skylines, 2,500 feet of 2-inch; skidding line, 3,200 feet of 1½-inch, line speed 600 feet per minute; receding line, 5,500 feet of 1½-inch, line speed 1,800 feet per minute; slack puller, 3,000 feet of ⅝ inch. The consumption of fuel oil is 800 gallons per day. The total wire rope used is 8½ miles. The annual production is 20 to 35 million feet, board measure per year (1½ to 3 million cu. ft.). The outfit requires a crew of 23 men. The use of such equipment makes it somewhat uneconomic to extract the small timber with the large. As a result in the past much timber has been left in the forest to be burnt after logging is over.

Foresters are familiar with the western method of selecting a spar-tree and the spectacular job of the 'high rigger' who climbs the tree (selected for height and strength). After lopping off the top he proceeds to attach to the tree a rigging somewhat like that of a ship's mast until it is anchored all round to nearby stumps by heavy steel cables more than 1 inch thick. Between this spar-tree and the top of the mast of the tower skidder runs the aerial ropeway which draws in the logs over a wide area to the railway line on which the skidder sits.

It is possible to log most of the year round in British Columbia, in contrast to eastern Canada where the seasons are more extreme. When the logs arrive by road or by rail at the saw-mills, or at the lakes or sea, the loads are tipped off into the water and taken to booms where they are sorted and sized. At several places were seen one-man tug-boats able to turn in their own length and capable of sorting all the logs in a boom. Before the logs go up the jack-ladders into the mills they are usually cross-cut by reciprocal saws which can cut under water, or by circular pendulum-saws up to which the logs must be lifted out of the water. Plywood logs are usually cut into 8-ft. lengths, and western red cedar logs into shorter or longer lengths according to the class of shingle or other mill for which they are intended. Cross-cutting at the mill enables the operators to transport their logs from the forest in lengths up to 40 feet or more. The practice is thus comparable with that of the hardwood trade in England but very different from the methods used with softwood trees in Scotland. The British aim in both cases is to use up the whole tree, whereas in British Columbia it is the practice to discard the upper part of the tree and any very rough or unshapely logs.

The western Canadian customs will change gradually as the second-growth timber becomes the main crop. The tendency will be to market such timber long before it reaches full maturity. One instance was quoted of a farmer selling cedar poles, 40 feet long, 12 to 14 inches diameter at the butt, from woods which

were 50 to 60 years old. Another case was quoted of a small owner of a 55-year-old plantation of Douglas fir who is extracting 200 trees per acre, 8 to 11 inches in diameter, for hewn railway sleepers, and leaving 220 trees below 8 inches and 30 trees above 11 inches in diameter per acre.

Such crops of trees, relatively small in size and young in age, present a striking contrast to the superb virgin forests of huge trees, the accumulation of centuries of undisturbed growth. The precise differences in quality between the sawn timber obtainable from each of these types of crop are an important subject for unprejudiced research and practical valuation.

LITERATURE REFERENCES.

- (1) Bill No. 7 (enacted 3rd April 1947), amending Forest Act 1945.
- (2) *Canada's Forests and the War*. Dominion Forest Service. (Report prepared for the Fifth British Empire Forestry Conference, 1947.)
- (3) Forest Act (Consolidation 1945) B.C.
- (4) *Forestry in British Columbia*. (Statement prepared by Forest Service for the Fifth British Empire Forestry Conference, 1947.)
- (5) Gilmour, John D.: *Observations on the Growth of the Next Forest Crop in the Lower Fraser Valley and Southern Vancouver Island*. Published by H. R. MacMillan Export Coy., Ltd., Vancouver, 1945.
- (6) MacMillan, H. R.: *Forests for the Future. Conditions essential to a Sustained-yield Policy for Management of British Columbia Coast Forests*. Published by H. R. MacMillan Export Coy., Ltd., Vancouver, 1945.
- (7) McElhanney, T. A. (Superintendent, Forest Products Laboratories of Canada): *Conservation by Better Utilization*. Dominion Forest Service. (Paper presented to Fifth British Empire Forestry Conference, 1947.)
- (8) Oregon State Board of Forestry, *Bulletin No. 10*, April, 1944.
- (9) Sloan, Gordon McG.: *The Forest Resources of British Columbia*. Printer to the King's Most Excellent Majesty. Victoria, B.C., 1945.
- (10) *Statistical Record of the Forests and Forest Industries of Canada*. 3rd ed., 1947.



FIG. 1. Standing tree in foreground, third from left—470 years old; 217 feet high; 7 feet in diameter at butt (saw cut, over bark); contained 14,827 board feet = 1,235 cu. ft.



FIG. 2. The butt of the tree, after felling.

DOUGLAS FIR (*Pseudotsuga taxifolia* Brit.) Franklin River,
British Columbia

(Photographs by courtesy of B.C. Government)

PLATE V

AN OCCURRENCE OF THE LESSER PINE-SHOOT BEETLE
(*Myelophilus minor* Hart.) IN THE NEW FOREST, HAMPSHIRE,
SEPTEMBER 1947, IN SCOTS PINE (*Pinus sylvestris* L.)

BY E. WADDELOVE AND H. WEBB

(Students of Gwydyr Forester Training School, Forestry Commission)

THE normal distribution of the Lesser Pine-shoot Beetle (*Myelophilus minor* Hart.) in Great Britain extends from Perthshire to the counties of Forfar, Kincardine, and Aberdeen in north-east Scotland. It is not recognized as a normal breeding species in south Scotland and England. Its appearance in southern England is, therefore, of some interest.

The last occasion on which it was found near the New Forest area was in 1942, when it was discovered attacking *P. pinaster* at Blake Hill, Parkstone, Dorset. In that instance the tunnels were comparatively poor specimens but beetles were present. The tunnels found in 1947 were very good specimens but no beetles were present.

The Lesser Pine-shoot Beetle breeds normally in the thinner-barked portions of the stem and branches, and prefers standing trees. Its numbers are always smaller than those of the Greater Pine-shoot Beetle (*M. piniperda* L.). It is likely that the habit of breeding in the thinner bark has some connexion with this inferiority in numbers, as the favoured breeding material retains its suitability for a comparatively limited period. This limitation would prevent the build-up of a very large population.

The tunnels were found on a thin-barked log of Scots pine (*Pinus sylvestris* L.) which had been lying for several months in a saw-mill yard at Holmsley, New Forest. They were recognized by the characteristic pattern which was clearly discernible at some distance. The bark was dry, no adults were found, and the tunnels appeared to have been deserted for some time. In the accompanying photograph it will be noticed that there is a fair concentration of the two-armed transverse tunnels of *M. minor*. Actually, 12 transverse tunnel systems of *M. minor* and 3 vertical tunnels of *M. piniperda* can be seen. Some of the *M. minor* tunnels occur in close proximity, which renders it difficult to estimate how large a population of adults emerged. Further, it is not known how widely distributed the species is in the neighbourhood where these logs were cut.

Subsequent investigations revealed further evidence of the insect on recently felled timber in Wootton Inclosure, from which the original log was extracted. No beetles were found on this occasion but elytral remains were present.

A more detailed inspection of four 'Red Tops' (Scots pine) in Wilverley Inclosure, some 2-3 miles away, felled because of insect damage, provided the following data:

1. On 24 feet of a specimen log there were 48 tunnels.
2. In 42 cases the larval galleries reached an average of 75 per cent. development.

3. On the same portion of the log there were also 48 tunnels of *M. piniperda*.
4. There was little or no interference between the two species or between tunnels of the same species.
5. A peculiar feature was that the tunnels of *M. piniperda* were all on the north side of the trunk whilst those of *M. minor* were on the south side.

It seems evident, therefore, that the Lesser Pine-shoot Beetle is established as a breeding species in the New Forest, but from the economic point of view, owing to its breeding habits, it is unlikely to assume the same degree of importance as the Greater Pine-shoot Beetle (*M. piniperda*).

The authors are indebted to Dr. R. Neil Chrystal for his advice and assistance during the investigations.



Billet of Scots pine (*Pinus sylvestris* L.) from the New Forest, Hampshire, showing a number of the 2-armed, transverse, gallery systems of the Lesser Pine-shoot beetle (*Myelophitus minor* Hart.) and three of the longitudinal vertical, tunnel systems of the Greater Pine-shoot beetle (*Myelophitus piniperda* L.). The latter galleries can be seen at the foot of the picture.

SOCIETY'S AND OTHER NEWS

EXCURSION AND ANNUAL GENERAL MEETING

PRELIMINARY arrangements have been made to hold this year's excursion in Lincolnshire and Nottinghamshire, with headquarters in Lincoln, from 27 September to 1 October. Members were given details in a circular dated 23 June last. The last date for entering is 14 August. The 21st Annual General Meeting will be held on 28 September and an agenda will be issued in due course.

NOMINATIONS FOR OFFICE-BEARERS AND COUNCILLORS

MEMBERS are reminded that, under Article X and XI and Rule 3, written nominations for Office-bearers and Councillors have to be in the Secretary's hands by 31 October. This year one of the five vacancies on the Council may be filled by a Professional Associate, and candidates for this vacancy must be nominated by two Professional Associates.

THE MURDOCH TRUST

MESSRS. SHEPHERD AND WEDDERBURN, W. S., 16 Charlotte Square, Edinburgh, 2, have notified the Secretary that members of the Society who are interested in the above trust may write to them. Under the will of the late John Murdoch, Craiglockart, Midlothian, donations or pensions (renewable annually) may be granted to scientists who are bachelors or widowers, not less than 55 years of age, and in need.

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS DIVISION OF FORESTRY AND FOREST PRODUCTS

A EUROPEAN Working Group of the above Division has been detached to Geneva to attend to regional activities in Europe. Mr. D. Roy Cameron, formerly Dominion Forester, Ottawa, is in charge. A link has been established with the Economic Commission for Europe, and joint consultations have taken place on short, medium, and long-term problems in forestry and forest products.

FROM July–August 1947 F.A.O. began publication of an international forestry review, *Unasylva*, to appear every second month. A high standard has been set and a number of exceptionally interesting and authoritative articles are included in the first four issues, reviewed briefly under 'Notices', below.

TIMBER DEVELOPMENT ASSOCIATION, LTD.,

75 CANNON ST., LONDON, E.C. 4

THIS Association continues to do very useful and widespread educational work in timber technology. Evening classes have been organized for 1948–9 in some 57 towns of England, 5 of Scotland, and 1 of Wales, where those in the timber trade or interested in timber can get instruction. Much emphasis is laid on the identification of timbers by eye, hand-lens, or microscope. This is a sound basis from which to proceed to the proper use of the timbers concerned. As the work develops, it is to be hoped that identification will take its proper place as a means to an end; and that the good utilization, statistical and constructional research work of the Association will be linked with much-needed instruction in the case for sound forestry and sustained yield working throughout the world. With such forestry and

working, future timber supplies can be assured; but at present many regions, particularly in the tropics, are heading for exhaustion. Even in the United States of America the cutting practice on 64 per cent. of private forest land is classed by the Forest Service as poor to destructive. The large owners are rapidly waking up to the need for sound practice but the medium-sized and small owners, holding 85 per cent. of the private forests, have still to be educated and roused to their own responsibilities and true interests.

FORESTRY COMMISSION: EXHIBITS AND DISPLAYS AT THE AGRICULTURAL SHOWS OF 1948

Education on the Fire Hazard

THE Forestry Commission has staged exceptionally good displays at the chief agricultural shows of 1948, in England, Scotland, and Wales. In this they have been well supported by private forest owners, the Imperial Forestry Institute, Oxford, and others, including the Forest Products Research Laboratory, Princes Risborough (Dept. of Scientific and Industrial Research).

At the Bath & West Show, Cardiff, repeated small-scale demonstrations of actual fires in young conifer plantations (set up for the purpose in a safe part of the Show park), and their extinction, were a great success, judging by the remarks of adults and children in the crowds who followed with zest the demonstrations there by Mr. G. B. Ryle and his collaborators. The importance of educating the public in this matter is plain from the appeal to holiday-makers which the Forestry Commission was impelled to issue in July 1948. Up to that month of the year more than 1,100 fires in State forests had been reported, and 1,800 acres of woodland had been burnt, with a financial loss of £43,000. This was considerably more than the average since the Forestry Commission was established.

LETTERS TO THE EDITOR

*From the Chief Forest Research Officer,
Union of South Africa.*

Pretoria,
12 March 1948

Dear Sir,

Replicated Thinning Experiments

The article on the 'Bowmont Norway Spruce Sample Plots' by F. C. Hummel, which appeared in Volume XXI, Number 1, of *Forestry* has been read with much interest. At about the same time as the Bowmont plots were established similar replicated experiments were started in South Africa. The introduction of statistical design in forestry field experiments in South Africa was a notable advance, and our research has benefited considerably as a result. The first thinning experiments, which were laid out on substantially the same design as that used at Bowmont, were, however, not entirely satisfactory. It is fully realized that the character of the species, the site conditions, and many other factors influencing the growth of trees in South Africa differ widely from those prevailing at Bowmont, but it may nevertheless be of interest to compare results, here and at Bowmont, and to point out some of the difficulties which have been experienced with replicated thinning experiments of this type.

In South Africa, as at Bowmont, tenth-acre plots were found to be too small and the surrounds were also inadequate. Too few trees were left on such small plots, when heavy thinnings had been applied, to give expression to the treatment. The standard errors of means were also increased because so few trees were left on individual plots. Consequently plots used in thinning research were increased in size to 0.2 to 0.25 acre, with larger surrounds.

The 4×4 Latin square design is one that is not to be recommended statistically. This design leaves only 6 degrees of freedom for computing the error variance, whereas at least 10 to 12 are preferable.

In view of these considerations the Latin square design would appear to be unsuitable for thinning research, because if larger plots, wider surrounds, and more replications are introduced, an area large enough to accommodate the experiment is seldom available. Latin squares with larger plots, and 5×5 design, have, however, been used successfully in South Africa to test geographical races of *Pinus pinaster* (Rycroft and Wicht, 'Field Trials of Geographical Races of *Pinus pinaster* in South Africa': paper presented at British Empire Forestry Conference 1947).

The thinning grades applied on the Bowmont plots were determined on the basis of tree-classification without basal area or any other check. This method has been discarded in South Africa. It was found that the interpretation of the classes was not objective and that the treatments consequently varied when carried out by different workers. Standard prescriptions for B, C, and D thinnings are also contradictory in that certain tree-classes are set down for removal, but suitable trees of these classes are to be left if their removal causes a 'gap' in the canopy. The interpretation of the term 'gap' is subject to wide variations. When very heavy thinnings are applied the differentiation in the trees due to competition is so slight that thinnings cannot be satisfactorily defined in terms of tree-classes, a circumstance which tended to preclude the testing of heavy thinnings. It was, however, particularly desired to test such thinnings in South Africa.

To define a thinning unequivocally it is necessary to lay down the degree, in terms of basal area, number of stems per acre, or some such measure; to describe the nature of the thinning, for which tree classification is useful; and to lay down the lengths of periods between successive thinnings.

The Bowmont plots showed that the heavier thinnings applied produced more timber volume than lighter ones, and also larger and more valuable thinnings up to the date of the measurement. The question now arises whether still heavier thinnings would not have produced still better results. Experience in South Africa has indicated that this is likely to be so. There is a distinct possibility that the optimum thinning at Bowmont lies outside the range investigated.

It is stated that height growth at Bowmont was the same under all thinning treatments. Probably none of the treatments were heavy enough to affect height-growth sufficiently strongly, so that differences could be shown to be significant. Heavy thinnings applied in South African pine stands have had a marked effect on height-growth. It has been established, however, that diameter growth is more sensitive to suppression than height growth.

In the first South African experiments B, C, and D thinnings were also tested, but later when it was considered necessary to include early heavy thinnings, degrees of thinning, defined in terms of stems per acre, were laid down to cover the entire range.

The statement that 'Without replication no statistical treatment would have been possible, and the interpretation of results would have been largely a matter of personal opinion' is true only if the treatments are not related, e.g. when various races of a tree species are compared. If the differences in treatments are variations of degree, which can be expressed in terms of a single variable, then the position is different. Thinning degree can, for example, be expressed in terms of numbers of stems per acre. If a number of plots, not replicated, are thinned to various degrees, it should subsequently be possible to compute regressions of mean diameter, mean height, dominant height, total timber volume yield, and other variables on degree of thinning. If these regressions are significant, then treatment will have had a real effect. Variance due to deviations from regression will provide an estimate of error. There are also other ways in which regressions, and other forms of co-variance analysis, can be used. The possibilities are at present being examined in detail, and it is hoped to report fully on the results in the near future.

Some ten years ago a number of *Correlated Curve Trend* projects were devised by the South African Forestry Department, in which various correlated thinnings, defined in terms of stems per acre, were applied at random without replication. The intention was originally to apply mechanical, graphical smoothing and harmonising of curves only. These projects will, however, yield data suitable for statistical analysis on the lines indicated above, and they thus promise to provide a new approach to thinning research which will simplify field experiments, and also provide much more comprehensive results than replicated experiments of similar extent would yield. Eight correlated degrees of thinning can, for example, be tested on eight plots. If replicated at least four or five times as many plots would be needed.

It is not desired to detract in any way from the credit due to those who started the Bowmont and early South African replicated thinning experiments, which have in spite of shortcomings nevertheless yielded significant results. It is merely intended to indicate that there are to-day alternative procedures, not available in 1930, which should be explored when new thinning experiments are initiated.

It would be of great advantage in thinning research if it were possible to do without replication, and thus obviate the need to find excessively large uniform areas for experi-

ments. Although much has been learnt from experiments such as the one at Bowmont, comments by Mr. Finney, who assisted with the statistical interpretation of the Bowmont experiments, on the possibility of simplifying experiments, as indicated briefly here, would be of considerable interest.

Yours faithfully,

C. L. WICHT.

(Chief Forest Research Officer,
Union of South Africa)

Comments by MR. F. C. HUMMEL on Mr. Wicht's Letter

The application of statistical methods to thinning research opens up possibilities that have only partially been explored, and Mr. Wicht's stimulating letter on the subject should be of considerable interest to all foresters engaged in research.

In Great Britain, as in South Africa, experience has shown that, for the reasons given by Wicht, the Latin square is not usually suitable, and also that thinnings should primarily be defined in terms of a single measurable variable and not by the tree classification, although this tree classification is useful as an addition to the quantitative definition.

We differ, however, from Wicht in the alternatives that we have chosen. He suggests defining thinnings in terms of number of stems per acre, basal area of main crop, or some such measure. Our limited experience suggests that number of stems per acre is suitable for experiments designed to find out the most suitable height or age at which to start thinnings, but that in experiments where thinnings in all the plots commence at the same time and differ only in severity, Lexen's index of stand density is preferable. This index is obtained by multiplying number of stems by mean breast height girth by mean height.

In choosing the design of our thinning experiments in Great Britain we are limited by two major considerations. The first is that replication is essential. In this country the main factors governing growth vary considerably and sometimes unexpectedly and independently of one another, even within one forest; and a thinning treatment can only be recommended for application in practice if it has proved its worth in several localities. The second consideration is the need for uniformity of growth conditions within any one replication. In practice this limits us to 3 or 4 quarter-acre plots, each with a surround of a $\frac{1}{2}$ chain, and even for this layout it is often extremely difficult to find sufficiently uniform areas.

Each replication of 3 or 4 plots can be treated as a block in a random block experiment in which the number of degrees of freedom for calculating the error variance depends on the number of replications. The regression of the various growth factors on stand density is calculated by the use of orthogonal regression polynomials. The difficulty that arises from the various blocks not all being the same age or height when they are established as sample plots is partially overcome by the fact that stand density as defined above is kept constant with age for any one thinning treatment. None of these block designs is as yet ready for analysis, and until this stage is reached, it is impossible to foresee how best to tackle other difficulties that may arise.

In suggesting the use of regression in an unreplicated series of 8 plots, each thinned to a different number of stems per acre, Wicht no doubt realizes that he only has six degrees of freedom for estimating the error variance if, in calculating the regression of each factor (such as diameter or volume) on thinning treatment, he merely uses plot means or totals; but there appears to be no valid reason why the precision of the estimate of error should not be increased considerably by taking into consideration the measurements of individual

trees or groups of trees in each plot instead of merely the plot means or totals. The most suitable way of utilizing this additional information will have to be evolved in the light of the available data.

Further news of these South African thinning experiments and the methods adopted to analyse them is awaited with keen interest.

F. C. HUMMEL.

(Mensuration Officer, Forestry Commission)

From MR. D. J. FINNEY

Lecturer in the Design and Analysis of Scientific Experiment, University of Oxford

3rd August, 1948

Sir,

Replicated Thinning Experiments

May I offer one or two comments on the discussion of Mr. Hummel's recent paper, which you have been good enough to show me?

I think that Mr. Wicht rightly draws attention to the inadequacies of the 4×4 Latin square, which because of low replication and the few degrees of freedom for 'error' cannot provide a very sensitive test of treatment differences. The design can be valuable for a series of like experiments on different sites, whose results are eventually to be combined, but for a single experiment something a little larger is preferable: two 4×4 squares, side by side, have often been found useful in agronomic investigations. In forestry, however, the difficulties of finding a compact area of tolerably uniform land may restrict the use of Latin squares and favour the rather more adaptable randomized block designs. Whether or not this is so can be decided only after examination of the results of many experiments or of 'uniformity trials' (areas of uniformly treated forest measured and recorded in individual small plots which can be analysed as though they related to several different experimental designs). This empirical approach has shown the advantage and limitations of different designs in agricultural experimentation, and it, rather than argument from general principle, will be the final arbiter on the relative merits of these designs in forestry.

Wicht's suggestions of using a regression relationship of yield on degree of thinning in order to assess error variance may sometimes be helpful. Unless many different levels of the variable representing degree of thinning are tested, however, in the absence of replication there will be difficulty in ensuring that the right form of regression equation (linear, quadratic, or other type) is used. The problems of block and plot size seem still to be present, for it is desirable that the various levels of thinning be tested on uniform land, and there is likely still to be a shortage of degrees of freedom for the error variance. I cannot understand the proposal, in the penultimate paragraph of Mr. Hummel's comments, to use measurements of individual trees: this appears to be based on a misconception of the meaning of the estimate of error.

I have too little experience of forestry problems to discuss the opinions of Mr. Wicht and Mr. Hummel on the definition of thinning treatments, but Mr. Hummel's paper, and the comments on it, make clear the need for much more extensive study of the technique of experimentation in forestry. Merely to lay down a miscellaneous collection of plots is not enough. Even a short acquaintance with British experimentation in forestry convinces me that a great amount of hard and conscientious work has often been put into experiments that, by their very nature, were incapable of answering the questions they were intended to solve. Care in the conduct of an experiment is important, but it cannot compensate for lack of proper planning before the field work is begun. Time spent then in consideration

of the purpose of an investigation, the treatments and measurements relevant to the study, the experimental design best suited to the questions at issue and the choice of site, plot size, and block shape and size is seldom wasted. The Bowmont experiment and those in South Africa mentioned by Wicht must not be regarded as the last word in experimental design, but as steps towards an adequate programme of experimentation. Full development will be expensive and laborious, but these difficulties are imposed by the nature of the problems, not by the perversity of statisticians.

Yours truly,
D. J. FINNEY

From DR. MARK L. ANDERSON

Beeting

Sir,

There are many unsuitable words and expressions in our forestry vocabulary, but one of the most unsatisfactory is the term 'beating up' which is now very generally used to stand for that cultural operation which is concerned with the replacement of failures in a plantation by putting in new plants. The term is a relatively modern one which should never have been allowed to gain currency, at least in England where the older technical term which was used when there was a real forestry tradition in the country was 'mending over', as freely employed by Billington, for example, in his *Facts, Hints, Observations, and Experiments on the different modes of raising Plantations of Young Oaks*, published in 1825. For many years past I have been quietly carrying on a campaign for the replacement of the mongrel expression 'beating up' by the proper term 'beeting', which, if the Forestry Commission must use a Scots word to denote the operation of mending over, is the correct one to use. I well remember the derision which greeted my assertion at a meeting many years ago of the Royal Scottish Forestry Society that the proper expression should be 'beeting', certainly in Scotland. Imagine my chagrin, therefore, to find that you, Sir, in my recent review of Mr. Edlin's book, had seen fit to 'correct' me and to change my perfectly proper 'beet' to 'beat'—in inverted commas!

It is perhaps unnecessary for me to point out that in the Scots tongue the word 'beet' is correctly used to mean 'mend' or 'repair', applicable not only to young plantations but to fires, to walls, and even to love. Anyone who doubts this need only refer to the new *Scottish National Dictionary*, where many examples are quoted. Moreover, it is surprising how few people are aware that the word 'beet' is also given in the best English dictionaries, meaning 'to repair'. In both cases the derivation is from the Anglo-Saxon *betan*. There is thus no reason why English foresters, if they so wish, should not replace 'mend over' with 'beet'; but why 'beat up'? Scarcity of paper should decide them, if not the fact that the word 'beat' already has a commoner meaning.

In Scotland, however, if the Scots forester has any regard for tradition, the precedent for using 'beet' is a very old one. In the early part of the nineteenth century, when there was a real native forestry in Scotland, one of the first text-books on forestry, or planting as it was then called, appeared in 1803 under the name of Walter Nicol and the title of *The Practical Planter*. In it the term 'beet' is correctly applied on several occasions and there is, in fact, a special section headed 'Beeting or Filling up of Vacancies'. It is to be noted that he gives 'beeted' as the past tense of the verb.

It is not easy to appeal successfully to tradition in forestry matters when many practising foresters firmly believe that 'real forestry' began only yesterday. In this connexion, Sir, I think it may be of interest to mention what happened so recently as 1941 in France,

where they have rather a different outlook. At a meeting of the Council of State to consider the drafting of new forestry legislation, the Council asked the exact meaning of the words *glandée*, *panage*, and *paisson*. The Forest Service representative explained that *glandée* and *panage* were synonymous terms, applicable to the running of pigs in the forest so that they could devour acorns, whereas *paisson* signified that the nourishment of these animals was specially provided by beech-mast. It was suggested that the one word *panage* would suffice for all. The Council were also critical of the term *bêtes aumailles* (horned beasts), but the Service representative defended the expression as being one actually current in the technical language of the Service.

Things might have gone badly for these ancient terms had not M. Canet, one of the councillors, intervened. 'It had to be conceded that they were here dealing with expressions which were in use in the Forest Service, which,' he said, 'was one of the few services which had known how to retain intact all the traditions which once were honoured by the entire French civil service.' He was astonished that the Council had chosen the moment when the Marshal had asked that the old traditions should be restored to honour, in order to refuse to insert in the forestry code a traditional forestry expression. The meeting was immediately converted and the horned beasts occupied the place destined for them. The terms *glandée*, *panage*, and *paisson* were likewise preserved.

Later, gratitude was expressed by members of the Service to M. Canet for defending the retention in a legislative text of an expression in current and traditional use in the forestry vocabulary. Surely that is how it should be!

I should like to make an appeal for the retention in our forestry vocabulary of the traditional terms, 'beet', 'beeted', and 'beeting', but I confess that it is less easy to break a bad habit than a good one, nor is this the only forestry expression whose genealogy requires to be investigated.

I am,

Yours sincerely,

MARK L. ANDERSON.

(Imperial Forestry Institute, University of Oxford.)

(We are indebted to Dr. Anderson for this correction and support his appeal. *Editor.*)

REVIEWS

Report of the New Forest Committee, 1947. Cmd. 7245. H.M. Stationery Office.
3s. 6d. net.

Review by E. W. JONES

THE above Committee, whose report has recently been published, was set up in the spring of 1946 'to investigate the state and condition of the New Forest and, having due regard to existing rights and interests, to recommend such measures as they consider desirable and necessary for adjusting the Forest to modern requirements'. The Committee consisted of the Rt. Hon. H. T. Baker, P.C. (Chairman), Lord Lucas of Chilworth (English National Committee, H.M. Forestry Commission), and George Langley-Taylor, Esq., Vice-Chairman of the Council for the Preservation of Rural England, with the Deputy Surveyor of the New Forest, D. W. Young, Esq., as Secretary. The report is valuable both for its survey of the history of an area where so many jealously guarded ancient rights and customs have survived to complicate administration, and for its careful recommendations. The principal interests to be reconciled are on the one hand those of the Commoners and on the other those of the nation in its various aspects. The main interest of the Commoners is that of grazing their cattle, and to this end they expect that pastures should be extended, drained, and improved, and they look with the strongest disapproval on any sort of enclosure. For some years past the New Forest has been administered in relative peace, but the strife between Commoners and Crown which enlivened the Forest in the last century is still latent, as the evidence given by one Commoner with respect to further enclosures shows—'we have been fighting to get back land which was taken from us centuries ago; the Act of 1877 gave us what we were fighting for; we call it our Charter; now if we give the power to the Forestry Commission to take what they want we shall be put back to where we started'.

The various interests of the nation are themselves somewhat contradictory—on the one hand timber production, and the needs of the armed forces, and on the other the physical and spiritual health of its people and the preservation and scientific study of its natural history.

The report makes it quite clear that although the right of grazing has been exercised without any serious restriction, the potentialities of the forest are not used to the full. Thus during the recent war the number of cattle grazed in the forest was trebled, and despite the enclosure of nearly 9,000 acres—some 13 per cent. of the Crown Lands of the Forest—for defence purposes, there was no question of overgrazing. Before 1939 the Forest was used regularly every summer for military manœuvres, and on an earlier occasion when there were proposals afoot for extending the area of enclosure, the demand of the Military for open spaces for training is said to have been one of the decisive factors in preventing such extension. The Committee recommend that this use of the forest should cease. During the recent war aerodromes totalling 2,400 acres were made, together with bombing ranges, &c. These and many other encroachments on the forest were only tolerated because of the urgency of national defence, and with at least the tacit understanding that as far as possible the ground should be restored to its former condition and any damage made good. Now, the Committee point out, the removal of runways, concrete foundations, brick buildings, &c., is being shirked on grounds of expense, and there are proposals for utilizing aerodrome buildings for other purposes, and for extending 'temporary' factories and other plant

erected during the war along the shores of Southampton Water on land which, though not technically within the forest bounds, is in effect an integral part of the forest, and where the existence of a large industrial area would inevitably destroy the amenities of a large part of the forest. Speaking of all these actual and threatened depredations, the report says: 'In the first place there is a tendency to regard the disfigurement as of no great importance. In the second place there is an even more dangerous tendency to treat as a precedent the breach of the Forest laws which these encroachments entail. This is in striking contrast with the anxious care manifested by the Planning Officers in their Reports. . . . If the Forest is to be preserved in these days of speedier transport, not only must the existing laws be carefully maintained, but severe restrictions must be placed on the use of the land which constitutes the forest and its surroundings. We support the proposals of the Planning Officers, and we are concerned to note a disposition not merely to set aside their opinion, but to argue that, as there is a grave housing shortage, the aerodromes should be used as temporary villages, and that as the war has left the country impoverished, industries and factories should be set up in places where they would menace the Forest. We cannot over-emphasise the danger of all this. A breach permitted today will assuredly be followed tomorrow by a breach of a more serious character.' . . . 'In 1939 everyone regarded the Forest as a national heritage which must be preserved at all costs. After the war it remains just as much a national heritage and is no less but even more precious. Unless a determined stand is made now the country will lose it.' Probably most people except officials of the Government departments concerned will agree with these pointed remarks, and feel that there are many other places where war-time encroachments have been made to which they apply equally well. They have been quoted at some length because it seems as though strong public opinion were needed to carry this point of view against officialdom, and to ensure that the carefully made plans of planning authorities are not overridden by powerful government bodies.

As regards timber production, the report says that 'We have more than once expressed our conviction that the question of amenity is all important, and the use of the Forest for silviculture should be secondary'. In fact, three out of the four extensions of silvicultural activity suggested are subsidiary to other proposals. A twin trunk road from Cadnam to Ringwood is proposed. The two tracks are to be several chains apart, and the intervening space is to be planted, but 'in separate sections so as to provide a broken sky line and not to spoil views'. Secondly, belts of trees are to be planted in certain places along the eastern margins of the forest to screen off built-up areas. Thirdly, in order to ensure the future supply of 'ancient and ornamental trees', small enclosures not exceeding 20 acres each, and amounting to not less than 50 acres per year, are to be made and regenerated in the open woodlands. No comment is made on the cost of any of these three kinds of planting. For increased timber production it is proposed that an additional area of up to 5,000 acres should be planted. The areas would be selected by the Verderers as unsuitable for grazing, and the Verderers would have the power of deciding whether or not they would be available for a second rotation. There is no suggestion as to a minimum size of block to be enclosed, and it is clear that it would rest entirely with the Verderers whether this proposal were effective or not. It is suggested that the Commission pay a *minimum* of 2s. 6d. per acre per annum to the Verderers in compensation for the loss of the rights of the Commoners' animals to roam over the new enclosures—it is not specified who is to fix the actual compensation, presumably the Verderers—though it is agreed that as the land to be planted will be unsuitable for grazing, there will be no actual loss of grazing ground. It seems a little hard that, for the privilege of afforesting their own land, the Commission should be asked to pay compensation for a very intangible and theoretical loss, especially when,

primarily for the benefit of the Commoners, they repair 187 bridges, maintain nearly half the drains of the unenclosed forest, and destroy pine seedlings which are coming up on the open heathland!

To safeguard the indigenous flora and fauna it is suggested that the Forest be declared a 'Nature Reserve', and a 'Curator' be appointed by the Verderers, to take charge of the general protection of the wild flora and fauna. The interests of the scientist and naturalist are to be under the control of the Verderers, 'and not under that of any national scientific authority'. No reason is given for this suggestion. There is, of course, no national scientific authority which would be entirely satisfactory for such a purpose in existence at present, though proposals have been framed for creating one in the immediate future. It would at least seem reasonable that scientific bodies should have some closer control over their own interests than is suggested, and in particular over the choice and activities of the 'Curator'.

It is apparent that in many ways the duties of the Verderers are to be greatly increased. Under the 1877 Act their main duty was to 'control the grazing health of any animals in the forests' and to 'regulate the exercise of the rights of common'. It is now proposed that they should have many additional powers over the open forest, including absolute control over any further planting, the preservation of amenities, and the protection of the nature reserve. It is proposed that their number be increased from seven to eleven—a full-time Chief Verderer, appointed by the Lord Chancellor, with a council of ten. Of the ten, four are to be the elected representatives of the Commoners, two would be appointed by the Forestry Commission, two by the Rural District Council, one by the Ministry of Agriculture and Fisheries, and one by the Council for the Preservation of Rural England. This change in the composition and the powers of the Verderers is the most important single proposal that is made. One may wonder whether this body will be constituted in the best possible way for its new duties. Obviously much will depend on the choice and personality of the Chief Verderer, who will be an official nearly equal in importance to the Deputy Surveyor.

There are many other subsidiary proposals made, most of which are unquestionably sound, and it is clear that the Committee has done a very useful piece of work in its unbiased survey of the varied interests in the Forest and its attempt to find solutions that will be acceptable to all.

Forest Valuation: with Special Emphasis on Basic Economic Principles. By HERMAN H. CHAPMAN and WALTER H. MEYER. 521 pp. McGraw-Hill Book Company, Inc., 1947., New York and London. \$6.00.

Review by W. E. HILEY

THE earlier literature of forest valuation formed a very detached branch of forest science. It was bedecked with formidable formulae which appeared to have little relation with the forest as we see it and were seldom used by practical foresters. These formulae served, however, to convey a generalized picture of the relationship of income to capital and the influence of rotation, species, &c., on profit; and it was these general impressions, rather than the direct application of results of calculations, that influenced foresters in their schemes of management.

More recent writers on the subject have attempted to apply the theory of forest valuation to specific problems. For this purpose they have required actual figures of costs and returns, which can only be obtained from a close examination and a detailed analysis of books of

accounts; and, as these costs and returns seldom fit the well-known text-book formulae, specialized and, often, more complex formulae have been designed to meet the needs of each separate inquiry.

This tendency is well exemplified in Chapman and Meyer's *Forest Valuation*. In his preface Dr. Chapman defends the traditional concepts of forest valuation: 'In its problems and economic bearings, forest valuation differs in no essential respect from other fields. Notably in the evaluation of mining property, the practices and valuation formulas, based on texts issued 30 years later than Schlich, are identical in mathematical principles with those employed so much earlier in forestry. Even the investment firms have within the last 2 or 3 years belatedly adopted methods of evaluating stocks based on probable future net earnings.' Nevertheless, he claims 'that the treatment afforded to the subject in this book marks the final departure from the original European sources of forest evaluation and statics as set forth in Schlich's *Manual of Forestry*'. What I think he means by this is that he makes no attempt to collect together all the formulae which might at some time or other be required in calculations. Instead of this, he bears in mind the more urgent practical problems in forestry which may be solved by financial or economic analysis and guides the reader through the intricacies of thought which may lead to the required solutions.

The principal problems which are tackled in this manner are the taxation of forest property, the appraisal of damages, forest fire insurance, and the appraisal of stumpage values; there is also a chapter on the determination and application of conversion returns which contains a detailed analysis of the values of individual logs of various sizes within a forest crop. These problems are considered in the light of American experience and, although the general theory and the methods are of deep interest to British readers, the results are naturally inapplicable. Dr. Meyer's main contribution to the book is a chapter in which the methods adopted by the U.S. Forest Service in valuing stumpage are explained; the valuation is based on a detailed assessment of the logger's probable costs and the value of sawn lumber which he may expect to produce.

All the valuations in the book are based on the assumption that each entrepreneur will act according to the dictates of enlightened self-interest. But Chapman is much too thorough to take this premise for granted. He devotes the first six chapters to a discussion of general economics and justifies this from his experience, during 40 years of teaching, that 'the greatest difficulties always lay in the failure of the students to grasp certain fundamental economic laws'. These chapters are largely devoted to an exposition of the precepts of *laissez faire*, and the authors' viewpoint may be summed up in the two following quotations which are now more typical of American than of British thought:

'There is simply no doubt that private initiative is economically the most efficient, and centralized bureaucracy the most inefficient form of industrial management.'

'Loss of economic freedom, which is based upon and made possible only by the free movement of prices in free markets, leads inevitably to loss of political, intellectual, moral, and religious freedom.'

A very sharp distinction is drawn between *compound interest*, which applies to past operations and contracts and brings values up to the present, and *discount*, which is applied to estimated future costs and returns. We have, perhaps, been too ready to regard the present value of a plantation as just a particular point in the flow of compound interest curve which runs from the initiation of a crop to its final realization. This view is too theoretical for Chapman, and I think that his teaching leads to a more accurate and realistic outlook.

The subject is a very complicated one and the authors do not attempt to make it easy.

In fact, the book is very hard reading and only a determined student will get through it. But anyone who puts sufficient effort into following the close reasoning which it contains will enjoy the sense of achievement which comes from accompanying a deep and exact thinker through the processes by which he attempts to solve difficult problems.

Working Plans for Estate Woodlands. By N. D. G. JAMES. Basil Blackwell, Oxford. 1948. 6s. 6d. net.

Review by W. M. McNEILL

THIS little book of 90 pages, and a convenient size to slip into a coat pocket, is written by the Bursar of Corpus Christi College, Oxford.

The dust cover declares that the book has been written 'with the object of assisting those who have either to prepare a full Working Plan, or a more abbreviated "Plan of Operations"' as 'one of the requirements under the Scheme for the Dedication of Woodlands'. The author, in his Introduction, is rather more cautious when he describes his book as providing 'the basis of a working plan' for British estate woodlands (p. 4), and he specifically states 'that it is the method of preparing a working plan report for an estate that is being considered rather than the calculations and details of forest management covered by such a plan' (pp. 4 and 5).

He sets out the orthodox headings for a working plan and gives brief notes on the information to be recorded under each heading. The layout and headings are given for what is called 'The Full Plan', and progressive condensing and abbreviation are suggested for the 'Intermediate' and the 'Short Plan'. 'The Short Plan only covers such ground as is necessary to produce a working plan on lines suggested for the scheme of dedication' (p. 4).

There are no very serious criticisms to make of the general headings and their arrangement, except that the 'Objects of Management' should come at the very beginning of Part II and not, as suggested (p. 9), after questions of division of the area into management units have been dealt with. Again, in the notes on such supplementary prescriptions as Roads, Sawmills, Transport, and Staff (pp. 67-70), much of what is suggested for entry in Part II more properly belongs to Part I, which should be a full statement of present facts, upon which the resulting proposals of Part II are based.

The timing of the production of this book, coinciding with the official publication of the Forestry Commission¹ which gives the headings and forms to be prepared for the Plan of Operations, is rather unfortunate. The manner in which the Commission requires information recorded differs considerably from that suggested in the book under review, and to this extent one of its purposes is seriously affected.

There are estates which will need much fuller working plans than the minimum Plan of Operations, and for these this book will be useful. It does not, of course, tell owners how to write a good working plan, but it shows the kind of information required for a good plan and how it can be arranged. To assist owners and others to supply that information, a list of useful books and articles is given as an appendix. From this bibliography it would appear that a rather specially English viewpoint is taken, and some recent and relevant articles published in Scotland might have been included.

¹ *The Dedication of Woodlands: Principles and Procedure.* H. M. Forestry Commission Booklet No. 2, H.M.S.O., 1948.

Snowdonia. National Forest Park Guide. Issued by H.M. Forestry Commission. H.M. Stationery Office. 1948. 2s. 6d. net.

Review by T. THOMSON

IN acquiring large areas of land for its operations, the Forestry Commission often finds itself in possession of considerable areas which are too high or exposed for afforestation but very attractive on account of the beauty of the scenery, the interest of the native plant and animal life, and the opportunity they offer for healthy recreation. Such a tract is to be found in the Gwydyr Forest, which has a total area of 18,000 acres, stretching for 12 miles north and south and 5 miles east and west, chiefly lying to the west of the river Conway, from Afon Crafnant to the Afon Machno, and covering the lower reaches of the rivers Llugwy and Lledr. Whilst the area does not include the well-known mountain groups, Snowdon, the Glydyrs, and the Carneddys, it forms a fitting approach to these rugged mountains and has lesser peaks, rising at the highest point, at Creigiau Gleision, 2,213 feet above sea level. Its scattered lakes, ravines, streams, rivers, and stretches of open moorland offer a variety of scenery and interest to the rambler and to the student of geology, antiquities, and plant and animal life. The woods and plantations, besides forming features of the landscape, are themselves attractive and will become more so as they grow older and can be more freely opened to the public than they can be in the early stages.

In 1937 the Forestry Commissioners agreed to make the whole of Gwydyr Forest into a National Forest Park, so that the public could have free access to the hills and lakes above the new plantations. In addition to the Gwydyr Forest, the Commissioners have included the Beddgelert Forest of some 3,000 acres, lying on the other side of Snowdon, on the north-east slope of the Nantlle Range, and rising to the summit of Moel Gebog, 2,566 feet above sea-level.

The Guide to the Snowdonia National Forest Park is a well-illustrated brochure containing not only maps and information as to access, accommodation, camping sites, and walks round Bettwsycoed, but also a number of essays on the geology, antiquities, fauna, flora, and forestry of the area, all written by experts who know the district well. It is these articles which make the Guide really valuable, for they will not only stimulate the interest of visitors who have already some knowledge of the various subjects, but should awaken the interest of others to whose inquiring minds the country-side has been to a large extent a closed book. Quite rightly, the Guide does not confine itself strictly to the area included in the Forest Park, but, like the visitor for whom it is designed, strays over the boundary to the mountain massifs, to valleys, lake, and towns, to seek the most interesting features, whether it be ancient monuments, rare plants, bird life, or the sites of old legends of the district.

In Mr. Clough Williams Ellis's article on 'Beddgelert and its History', with his account of the reclaiming of the estuary which used to run right up to Aberglaslyn, thus transforming 'this lovely island-studied inlet into so many thousand acres of third-rate pasture', he makes the point that, wild as our country is, the widespread prehistoric remains, the network of dry-stone walls enclosing the infertile fields, the scattered farm-houses and cottages, all indicate that it has always been subjected to the influence of man.

With regard to the antiquities of Snowdonia, Mr. W. J. Hemp has taken the whole of north Wales as his province and, starting with the cromlechs, cairns, and mounds of prehistoric times, describes in succession the hill forts, hut circles, Roman forts and roads, medieval churches, castles and homesteads, houses, public buildings and bridges, mentioning the most interesting examples both within and without the boundaries of the Forest Park. A bibliography of the antiquities of north Wales is given.

Dr. Edward Greenly, the eminent north Wales geologist, gives a most interesting and readable account of the geological history of the mountains which are the great feature of

Snowdonia. A series of diagrams, illustrating the present geology of the land and what it was in past ages, brings out what must be a surprising fact to many, that the mighty Snowdon and its satellites are but the inconsiderable remains of a mountain mass many times more lofty. The story of how the processes of subsidence under the sea, volcanic action, pressure, elevation, glaciation, and constant weathering have led to the present condition of the district is told in a simple and readable way.

The plant life of Snowdonia is dealt with by Mr. N. Woodhead of the University College, Bangor. He describes the characteristic vegetation of mountain and moorland, marsh, bog, river, and lake, and mentions some of the rarer plants which can be found in the area. The field botanist will find the article very interesting and will know what to expect and what to look for when he visits the terrain; but perhaps the ordinary layman will find the list of plant names rather daunting, and it might be an advantage if some of the more prominent plants, which give the tone to the different types of vegetation met with, were described more fully. Perhaps in a separate essay a description of one of the walks mentioned in the Guide, with an account of the different prominent plants encountered on the way, might form a suitable introduction to the plant life of the area and lead to a closer study of it. A few photographs and simple diagrams to facilitate identification would help.

Mr. William Aspden's article on the fauna, as one would expect from such a well-equipped and practised exponent of the animal life of the country-side, is excellent. The ornithologist in particular will be attracted, because the park lies across one of the most important migration routes in Wales, as well as affording a breeding-place for a number of interesting species, such as the chough, raven, peregrine falcon, common buzzard, and others. With regard to the mammals, the rare pine marten has been observed by Mr. Aspden and others in the wooded parts. The author doubts whether there are any genuine British wild cats on the area, the specimens taken for them being really the descendants of domestic animals which have gone wild. The blue mountain hare, which in north Wales is practically confined to Snowdonia, was introduced about sixty years ago by Lord Penrhyn from Scotland. The golden eagle, which preys upon it in its native country, has apparently not followed it into Wales.

Mr. R. H. Smith's article on the forests and plantations gives not only a general description of the natural and artificial woods, but also an admirable summary of the many measures which have to be taken to establish and protect young plantations. Of all the articles in the Guide, this is the one which is most likely to appeal to all visitors, since it deals with the most important characteristic of a Forest Park in simple language. It gives the information the inquiring layman would wish to have about the plantations, the work that has gone to produce them, and the kind of trees employed. Attention is called to the danger of fire destroying in a few minutes the work of several years, and simple instructions are given on how to avoid the danger of starting fires and how to tackle one in its early stages. Beddgelert Forest, which has been the scene of experiments in the afforestation of peat soils, is also described, and a general account is given of the methods of dealing with these difficult sites. Altogether the article is calculated to give the visitor a real interest in the forestry of the area, and should do something to inculcate that 'forest sense' in which the British people are lacking.

The list of Welsh place-names and their meanings and guide to their pronunciation by Sir Ifor Williams will be welcome to the English visitor. The photographs with which the Guide is illustrated are excellent. Mr. Charles Howarth of Conway is responsible for the cover design, chapter headings, and maps which add greatly to the attractiveness of the brochure. It is not only a Guide to the park but also an authoritative description of the various features which make the area of Snowdonia so fascinating.

Natural History in the Highlands and Islands. By F. FRASER DARLING. (The New Naturalist Series.) Collins, London. 1947. 16s. net.

Review by JAMES FRASER

IN order that a forester may enjoy this book in full measure it is recommended that he should read first the concluding chapter, secondly the two prefaces, and finally the full text. Then no matter how much he may dispute the method of presentation of current forestry practice and the author's opinion of the foresters, he must admit that the statements made about forests and forestry methods suggest many new lines of thought and cause him to think about very well established observations in a new way. The author may on that account claim that so far as his forester public is concerned he has succeeded in reaching his object as defined by himself, even if he has left that forester section of his public somewhat discontented and disappointed with his valuation of their work and the work of earlier foresters. He has certainly added interest to the work of most foresters by the accounts given of the animal life, and especially the bird life, of the forest of the different types found in the Highlands, including the types resulting from what he somewhat obscurely calls 'Commission monocultural methods'.

Dr. Darling's definition of the nature of research—'Good research is orderly thinking plainly said'—is sound, and it is to be recommended to all writers without exception. Dr. Darling has strong views about sheep farming, forestry, sporting methods, and economics, and he has been impatient in dealing with the beliefs and practices of men who do not think as he does. That impatience is intelligible, but it is regrettable in a book of the standard of this book. The story of the Lochiel pine (p. 57) was worthy of a fuller investigation. The statements about the uneconomic nature of sheep farming deserve more adequate treatment of the financial facts. The description of moor burning as a means of preserving the *status quo* of a grazing (p. 93) is obscure, more especially when Dr. Fraser Darling's strong and definite views on burning are held in mind. Foresters have no desire to dispute the general conclusions reached by Dr. Fraser Darling about the destructive effects of sheep grazing and moor burning.

The opening chapter of the book directs attention to the strong influence of the geological formation on the economic value of the overlying soils. Foresters are very willing to admit the irrefutable arguments advanced in support of such fundamental beliefs. They find it almost as difficult to use those sound geological beliefs as guides in their forestry practice as it is to use the excellent general belief in providence and ethics for direction of their daily lives. The principles and beliefs are excellent but very remote, and for the present the forester in the Highlands feels that geologists could help him most by giving a more special account of the variations of the drifts which are to be found within very narrow limits in every forest, and to the causes which have given rise to those variations. Foresters were entitled to hope for some general teaching on those matters from Dr. Fraser Darling.

The charge that Scottish foresters have been slow to learn and use ecological methods in their work reads strangely. Many Highland foresters believe that within the narrow range of fertility conditions in which many of them are obliged to work they are able to distinguish grades of conditions which ecologists have not yet distinguished, and the foresters have been willing at all times to learn from ecology. The foresters have also been willing to try out their own beliefs and have been careful to avoid broadcasting of insufficiently founded beliefs. That their methods in establishing and tending forests are antiquated and inferior to the methods used in other countries can be maintained only by observers who have not taken the trouble to become acquainted with the foresters. The teaching of a forester is not effected by the collection of sound principles alone; and in every country in

the world the general principles of forestry must be supplemented by sound observation of particular conditions, and then by formulation of new general principles. It is probably true that in every country the forester's special problem is the regulation of the rate of decay of humus. The methods of regulating that decay are so many that general rules of world application are highly dangerous and 'what has worked' becomes the soundest and most scientific guide for future practice. Special forest conditions within an area may make the sound economic and ecological choice a single species forest; and economic considerations may overrule full ecological consideration in choice of species.

Dr. Fraser Darling has drawn an attractive picture of the present general forestry conditions within the Highlands of Scotland, and special thanks are due to him for the accounts of the earlier work by Dr. G. K. Fraser in *Studies of Scottish Moorlands*. In reading his description of the natural pine forest one is tempted to believe that his ideas have been formed mainly on east coast woods. His description of the variations found in natural Scots pine is not exhaustive. He may in future editions find it interesting to consider how quickly the 'natural' ground surface vegetation of a pine wood is established in planted pine woods.

The work gives an historical account of the process of destruction of the forests and explains how grazing, muir burning, and sport have all contributed to the destruction. Foresters might naturally have expected to reach Dr. Fraser Darling's views on the length of time necessary to re-establish the natural ground vegetation cover on areas where forestry enclosure has secured immunity from deliberate burning. The periods are varied and the variation might link up closely with the nature of the drift cover.

In assessing Dr. Fraser Darling's service to forestry one may estimate that in this work his greatest success has been not in establishing any new facts about the forest but in bringing out the position of forestry in the general economy of the Highlands. He has presented the case in a way that is attractive to a wide public.

The book is well produced and the photographs and plates are magnificent. They help the general statement of the case presented and are not mere decorations. Dr. Fraser Darling is to be congratulated on his success in obtaining the co-operation of the men with whom he has worked in compiling the book. He has acknowledged their help and has provided a useful bibliography.

'Pattern and Process in the Plant Community'. By ALEX. S. WATT. *Journal of Ecology*, xxxv. 1 and 2, Dec. 1947. (Presidential address to the British Ecological Society on 11 January 1947.)

Review by E. W. JONES

DR. WATT marked his migration from the Cambridge Forestry School to the Botany School by turning his attention from forests to communities of herbaceous plants—to heath, grasslands, and to the Scottish alpine vegetation, and he has been outstanding amongst British ecologists, perhaps indeed amongst those of any nation, for the patience and meticulous care with which he has studied the finer structural details of such communities, together with their variation in time and the relationship within them of species to species. Some of the fruits of these years of close study became apparent in his Presidential Address delivered to the British Ecological Society in January of 1947, and recently published. All who heard this address at once recognized it as making a major contribution to ecological thought. In it he stated his mature views on the nature of the plant community, basing them primarily on his own work, but correlating it with that of many others.

In this address Watt considers the plant community—to use his own phrase—as a ‘working mechanism’—something dynamic that is continually changing. Many previous ecologists have appreciated the fact that it must be of this nature, since just as in a human community the component individuals have only a limited life, and any stability of composition or structure must be the result of a dynamic equilibrium; but in general they have been content to leave the matter at this stage, and have made no effort to explain the mechanism whereby such apparent stability is maintained, nor even to ascertain how great the degree of stability really is. It is this mechanism and the extent of this stability which Watt has been investigating, and with which this paper is primarily concerned.

To summarize Watt’s paper effectively in the space of a short review would be impossible, and it will only be possible to criticize it effectively in the future when there is available a bigger accumulation of knowledge of an equally detailed kind, comparable to that which he presents, but from a wider range of communities. All that can be attempted here is to give some indication of his lines of thought, and to make a few general comments.

It is a matter of observation that the plant community is often patchy; species are neither uniformly nor even randomly distributed. The vegetation carpet often consists of a mosaic of patches of several different kinds; and in the case of several of the grassland, mountain, and bog communities it can be shown that these various kinds of patch are serally related phases, one kind developing out of another. Moreover, these phases follow each other in cyclical sequence. In any one patch a series of ‘upgrade’ phases culminates in a ‘mature’ phase, which Watt suggests is probably one of maximum productivity, and is followed by a ‘degeneration’ leading back to the initial condition. This patchiness is more apparent to the eye in communities of small plants, where the units of the mosaic may be only a few inches across, then it is in forests, but Aubreville and others have suggested that it occurs also in forests, and Watt now suggests that it is a fundamental feature of all plant communities. In the case of the forest the size of patch might presumably have to be measured in chains or even miles rather than in inches, and if large, only a part—perhaps only one—of the complete series of phases might be represented in any one piece of woodland. A community of this kind could be regarded as a mosaic of several distinct but serally related communities, one of which is a climax. To take an example from forest ecology, it is known that on suitable sites beech woodland can develop from ash woodland; moreover, gaps in beech woods often become filled with ash.¹ Presumably under natural conditions such a woodland would consist of a mosaic of patches of beech and ash, and it would be reasonable to consider this as a mosaic of patches of seral ash and climax beech. Moreover, if the patches were large, only one phase might be represented in the wood at one time. On the other hand, it could equally well be argued that owing to its sporadic seeding it would be exceptional for beech to be replaced directly by beech, and the interpolation of an ash phase would be a normal feature. In this case there would be no justification for regarding pure beech forest as a ‘stable climax’. The climax would consist of beech and ash alternating in time, and possibly forming a mosaic in space as well. The two communities would both be integral parts of the climax, merely representing different stages in a recurrent cycle, analogous in some ways to larva and imago of an insect. It is this second interpretation which is obviously the more natural for the various non-forest communities studied by Watt, and he suggests that it is also the more natural one for forests. He points out that even if there is no change in species during the cycle, there must be a homologous change of structure and of age-class composition, provided that regeneration takes place periodically and not continuously.

¹ Watt himself cites as an example the alternation of beech and birch—an alternation which is perhaps less common and less certain than that of beech and ash.

On account of the much smaller scale both in space and in time, the facts are much more easily ascertained in herbaceous communities than in forest, and the establishment of this interpretation for forest vegetation must depend to some extent on the comparison with herbaceous vegetation. Superficially there appear to be very important differences between the two types, which might invalidate the comparison. The herbaceous communities consist mainly of perennials, multiplying vegetatively, while trees multiply mainly by seed. Perhaps this difference is less important than might appear, for in at least some instances (e.g. *Agrostis* spp. in the Breckland) it appears that with age perennial herbs deteriorate in vigour and ultimately die, reproduction by seed being necessary. Even if reproduction by seed were not necessary, climatic variation would presumably cause variations in vigour and rate of spread, causing the predominance, sometimes of one and sometimes of another group of species, thus giving results of the same kind as those produced by sporadic seed years.

These suggestions fit in with many experiences and at best half-substantiated beliefs of the 'practical' forester—the difficulty of regenerating some species, experienced in both temperate and tropical climates; the alternation of spruce and silver fir; the inadvisability of following larch by larch, &c.

The forester is constantly demanding guidance from the ecologist—guidance as to the species that he can safely grow, the extent to which he can safely disturb the natural equilibrium, the silvicultural operations, and particularly the methods of regeneration which he may most readily employ. It has been very widely recognized that it is easiest to 'follow nature', and that the greater the departure from the 'natural' course, the greater the amount of work necessary, and the greater the difficulties and risks likely to be encountered. It has also often been widely assumed, with less justification, that what is 'natural' is necessarily good, while many even less justified assumptions are often made as to what is 'natural'—e.g. mixed age classes, complex mixtures of species, &c. The forester often fails to realize how much of the ecologists' façade is founded on theory only, and that in interpreting the natural course of events in the forest the ecologist suffers from the same major disadvantage as the forester—his life is too short—while his science is far younger.

Watt's paper should help to show foresters how complex the ecological picture really is, and how little ecologists yet know about certain of its features. It should lead them to realize that it is impossible to give simple clear-cut answers to many of their questions concerning the 'natural' type of forest or climax—perhaps even to mistrust those whose answers are too precise and categorical. It should also show them the value of the pursuit of ecological knowledge for its own sake, in fields far removed from their own, which are of no direct economic importance either to the forester or to the agriculturalist. In interpreting the behaviour of the forest the ecologist must always depend largely on experience gained from communities which are more easily comprehended, but it is essential that he should check his conceptions based on these communities by study of the forest.

NOTICES

Unasylva. (An international forestry review published every second month by the Division of Forestry and Forest Products of the Food and Agriculture Organization of the United Nations.)

IN Vol. I, No. 1, July–August 1947, after an introductory article on world forestry by Sir John Boyd Orr there are two outstanding contributions. One is by André Marie A. Aubréville on the tropical forests of Africa, their shrinkage under prolonged abuse, and the measures essential to save and develop them for the continent as a whole. The other is by Lyle F. Watts, Chief of the U.S. Forest Service, being a part of his official report of 1946 to the U.S. Secretary of Agriculture, reproduced by permission. It deals with the crucial question of timber shortage in the U.S.A. and the steps necessary to secure abundance of timber on a sustained yield basis.

No. 2 is a special issue devoted mainly to the international timber conference at Mariánské Lázně, Czechoslovakia, in April–May 1947. It has valuable articles on the Parana pine (*Araucaria angustifolia*) resources and industry of Brazil (by Tom Gill), the French plans for timber production in tropical French territories, forest policy in the United Kingdom, and the exportable timber resources of British colonial territories.

No. 3 has many interesting articles, including one on cellulose chemistry by Dr. Mark, Director of the Institute of Polymer Research, Polytechnic Institute of Brooklyn, New York, U.S.A., and at page 9 a striking reproduction of a superb photograph of *Sequoia gigantea* in Yosemite, by courtesy of the National Park Service, U.S. Dept. of the Interior.

Vol. II, No. 1, Jan.–Feb. 1948, is again full of interest and well illustrated. It has two particularly weighty articles. One is an outline of a general forestry policy for the tropics, by Justus W. Gonggryp, a senior forest officer of the Netherlands, with many years of service abroad, from the East Indies to the Caribbean.

The other article is 'Latin-American Timber, Ltd.', by William Vogt, Chief of Conservation Section, Division of Agricultural Co-operation, Pan American Union. It is pungent and well calculated to disturb any remaining complacency about tropical forest resources. 'Latin America may be said to face the problem, within its own borders, of at least 20 million and probably 40 million displaced persons, a dilemma that makes the solution of the European D.P. problem seem like child's play. These tens of millions are displaced not in a political sense, but in an ecological sense. They are concentrated on sloping lands, the cultivation of which, under our present economic system, can result only in rapid, and in many cases permanent, destruction of the means of subsistence. They are able to grow their own food, and fibers for clothing and other purposes, and to supply the needs of growing cities, only by a process of autophagy.'

Unasylva does well to call attention to such problems.

EDITOR

Fire Control Notes, Vol. 9, No. 1. January 1948. Forest Service, U.S. Department of Agriculture, Washington.

THE future of the helicopter is assured, according to the records of Frank J. Jefferson. Both for patrolling and for the emergency transport of fire personnel and equipment it can operate in a manner impossible either with ground transport or with normal

winged aircraft. From a slow crawl just above the tree-tops, for close examination or even for the individual control of campers, the helicopter can rise to secure a big over-all survey of conditions and cover up to 40 miles of perimeter in an hour's patrol. Spot landings have been made on almost impossible sites with fully effective loads of men and machinery. Counter-fires or small outbreaks can be artificially blown in the desired direction while the machine hovers low over the ground.

The helicopter is in its infancy as an item of forest equipment, and Jefferson rightly warns foresters to keep in the forefront of advancements and not to waste dollars on already obsolescent types. It is 'a service that gets me and what I need there right now'. 'It is a mighty easy way of getting from hither to yon without getting leg weary' and thus being fighting fit to tackle the fire.

R. W. Bower is very right in criticizing the oft haphazard manner in which hand fire-fighting kit is maintained at the store depots. To pull down the shovel you risk having an axe dropping across your arm. He has a very orderly tool store where all items of equipment are accessible, handle first, without disturbing the others. British foresters please copy.

C. H. Coulter stresses the need for keen, kindly, and correct contact between the forest fire staff and the general public, to encourage mutual respect of each other's requirements.

A. B. Everts describes advancements in the use of various foams and fog foams. Use in forest fire-fighting is not yet established, but further research will definitely not be wasted. In industrial fire-fighting 1 gallon of fluid produces about 10 gallons of foam. To multiply our forest water-supplies by ten is just what we want.

G. B. R.

Fire Control Notes, Vol. 9, Nos. 2 and 3. April and July 1948. Forest Service, U.S. Department of Agriculture, Washington.

ABOUT 33 per cent. of injuries and deaths in the U.S. Forest Service come from fire-control activities. Seth Jackson stresses the need for accident education amongst fire personnel, and a careful maintenance of all fire-fighting tools and equipment to ensure their safety on the job.

I. C. Funk and F. W. Milam give further details and constructive criticisms of the Bell Model 47 B helicopter as a reconnaissance and pay-load carrier for fire jumping. Much work requires to be done before the helicopter can be included in our normal fire equipment: at present safe maintenance takes 160 man-hours per 100 hours of flying.

The disk-dozer, being a set of two disk coulter ploughs mounted ahead of a small track-layer on the normal bulldozer frame and replacing the usual dozer blade, is highly praised by H. M. White for quick fire-line work. It would seem to be a type highly valuable in this country both for fire traces and for silvicultural afforestation purposes, and its development should be advanced. We all know the weakness of a tracklayer dragging a long heavy plough equipment behind the driver. A. B. Everts describes a combination 'fire-fog' unit used for burning grass firelines with a fog extinguisher to prevent spread of the flames on the 'danger' side. This presumes control on the other side to be immaterial. The powerful flame-thrower should be useful in this country for complete incineration of damp molinia types which could thus be rendered safe before the onset of the hazard season in February-March. We have toyed with this system, using inadequate torch guns, and given it up, but an adequate burner mounted behind a '4 by 4' lorry tanker would give a different story.

The Equipment Development Committee of the U.S. Forest Service gives a useful résumé of recent developments and tests of fire equipment, ranging from machinery to wetting agents and food containers. They evidently take modernization in their equipment very seriously, and perhaps Nash Boulden, who writes elsewhere with more than a suggestion that too many dollars are being spent to save the real fire-fighters from doing the real job of fire-fighting, is a voice crying in the wilderness. To substantiate his criticism he should compare old-time fire-damage figures (if available) with present figures, not omitting modern increased hazard due to a more widely travelling public in the forests. Nevertheless he may have 'got something' in his stigma on current over-organization and paper control of fire protection.

G. B. R.

The Arboretums and Botanical Gardens of North America. By DONALD WYMAN.

The Chronica Botanica Co., Waltham, Mass.; Wm. Dawson & Sons, Ltd., London, W.C. 2. Chronica Botanica, Vol. 10, No. 5-6, pp. 395-498. Price \$1.50.

THIS work, as the editor states, will be useful and stimulating to plant scientists and plant lovers all over the world. It is no bare catalogue, as the title might suggest. The introductory matter contains interesting articles on: Selection of the Site, Who is to Plan, How to Plant, What to Plant, Space Required, Costs, Labour, Equipment, Labelling and Mapping, and other subjects. The main part of the work is headed 'The Active Arboretums and Botanical Gardens of North America, Listed according to Geographical Distribution'. Ninety institutions are dealt with. The information about them has been obtained by a questionnaire. Then follows a charming feature, a portfolio of prints and photographs of botanical gardens and arboretums, old and modern—American and foreign—illustrating their development and present scope. Many of the plates included in this section are of great beauty and interest. There are also sections dealing with proposed arboretums and botanical gardens and with institutions which have been discontinued. The author is to be congratulated on a concise and interesting work.

H. G.-C.

EXTRACTS FROM *Forestry Abstracts*

THE following items are reproduced by permission of the Commonwealth Forestry Bureau, Oxford, from their quarterly journal. They include matter of special interest to British foresters, not received or noticed elsewhere in *Forestry*.

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Grateful acknowledgements are recorded for the permission to reproduce the items.

Vol. 9, No. 3, March 1948

[1411]. 09.4 (492). *De Nederlandsche boschstatistiek*. [*Forestry statistics of the Netherlands*.] Ministerie van Landbouw, Visscherij en Voedselvoorziening. 1946. pp. 24+plate. [Du.du.e.] F.C.A.H.

Data for statistics of the Netherlands forests, based on aerial photography and checked by field survey, were collected from 1939 to 1942. They include a classification of land by use and by ownership, and distribution by species in 2 age classes, all tabulated. Forest

maps, scale 1 : 25,000, were also made. It is proposed to check the statistical data periodically, following the 15-year cycle of the topographical service in its aerial photography.

[1433]. II.43.1 : 12.25 : 23.24 : 44.3 : II.47.21. DOMINIK, T. *Znaczenie mikroflory glebowej dla rozwoju sadzonek sosnowych*. [The role of the soil microflora in the rate of growth of Scots Pine seedlings.] *Przegląd leśniczy*, Poznań July, 1946 (7-12). [Pol.] P.R.

Describes an experiment carried out by the author in the forest district of Stary Tomysl (Western Poland) in 1937-8, to determine the effect of forest microflora on the growth of Scots Pine seedlings on old arable soils. Scots Pine plantations on such soils have, as a rule, succumbed to root rot when 20 to 60 years old. The author, presuming this dying-off to have been caused by the absence of a microflora suitable for forest trees, decided to attempt to inoculate arable soils with the microflora of a climax forest association. Three experimental plots (with three replications) were laid out on old arable land, a heavily manured and limed sand on clay, having a pH value from 6.5 to 7.5 and situated 100 m. from healthy, pure Scots Pine about 90 years old, standing on deep, fresh sand of pH 4.3. The plots were planted in the spring of 1937 with 1-year-old Scots Pine seedlings from a forest nursery. Forest soil from the A₁ horizon of the neighbouring Pine stand was dug in and mixed with the original soil in plots I, and put only in the planting holes in plots II; plots III served as controls. Next spring, seedling heights on I were 29-30 cm., on II 23-30 cm., and on III 22-23 cm., and their total length (stem plus root) 78-9, 66-72 and 55-6 cm. respectively. Seedlings simultaneously planted as a routine measure in the same forest that supplied the soil averaged 33 cm. in height and 74 cm. in total length. The roots of all seedlings had mycorrhiza, which on control seedlings showed greater morphological variety. This, according to the author, may have been due to the activity of some 'undesirable' fungi which might have caused the wholesale mortality of Scots Pine on old arable soils, though this theory could not be tested by isolating species. The author believes that inoculating with forest microflora even if limited to the planting holes (a cheap procedure) is of importance, as it assists the development of mycorrhiza on the seedling roots and also protects the roots from being affected by undesirable fungi found in old arable soils.

[1438]. II.47 : II.49.0 : II.42.1 (437). NĚMEC, A. *Vliv hnojení a vytrvalé lupiny na vlastnosti degradovaných lesních půd. Podzol s ortěstem v polesí Cep u Třeboně*. [The influence of fertilizing and of perennial lupin on the properties of degraded forest soils. Podzol with hardpan in the Trieschel bei Wittingau forest district.] *Repr. from Sborn. české Akad. zeměd.* 18 (2), 1943 (175-87). [Cz.g.]

Cf. *For. Abstr.* 4 (86). The present paper discusses the effects on the soil of combined heather clearing, mechanical cultivation, liming, fertilizing, and growing of perennial lupin. Over a period of 15 years the control plots, which were merely cleared of heather and cultivated, have continued to show stunting of Scots Pine and Norway Spruce, Alder has died out, and the soil profile reveals renewed podzolization and hardpan formation. On plots given the combined treatment, not only have the tree species shown thrifty growth, as previously reported, but the soil profile has developed the morphological features of a good brown forest soil. Marked differences have been brought about in the chemical properties of the soil, the controls being much the more acid and containing less N and less P₂O₅, CaO, MgO, and K₂O in the top 30-40 cm. It is chiefly to the chemical improvements in the soil that the success of the combined treatment must be attributed.

[1455]. 12.11.3 (485) : 05.3. SYLVÉN, N. *Årsberättelse över Föreningens för växtförädling av skogsträd verksamhet under år 1946*. [Annual report on the work of the Swedish Forest Tree Breeding Association, 1946.] Medd. Fören. Växtförädl. Skogsträd No. 44, 1947. pp. 38. [Sw.]

Detailed reports are made on work in progress at the main Ekebo station and the various branch stations. The following notes refer only to points of special interest: (1) *Picea abies*: Partial or complete colchicine-induced tetraploids continue to show great inferiority in growth compared with normal diploids, but no judgement of the value of the treatment is yet possible and work continues. At the Dalfors station a trial has shown that results from planting in an inverted turf in the planting pit are considerably better—especially where heavy grass growth or local waterlogging occurs—than those from planting in an inverted turf at the side of the pit or directly in the pit without a turf. (2) *Pinus sylvestris*: Practically all grafts made between 1941 and 1945 have flowered every year or every second year, abundant flowering occurring on grafts only one year old. Few cones have set so far, but there has been a plentiful supply of male flowers for artificial pollinations. Two-year-old presumed tetraploids are not nearly so retarded in growth, compared with normal diploids, as are tetraploids in Norway Spruce. Special propagating frames at the Sundmo branch have been used for two batches of grafts in one year: after about 3 weeks in the special frames the scions have formed shoots, and can then be shifted to ordinary greenhouse benches to make way for a fresh batch of grafts made with scions kept in cold storage. Established grafts can be put out into open beds for the winter. Studies are in progress at this branch on the influence of seed size and weight on plant size, sowing methods (with special attention to seed coverings), effect of shading on reproductive age, treatment of seed orchards for maximum seed production, susceptibility of Pine seedlings to *Phacidium infestans*, optimum seed-extraction conditions, &c. Transplanting of young Pines 2.5–3 m. tall was followed by precocious production of female cones only. At Dalfors a strangulation experiment on Scots Pine and Norway Spruce has shown that this method especially stimulates the production of male cones. Low availability of soil moisture also stimulates flowering. In the Dalfors trials of Scots Pine considerable difference has been noted between progenies of different mother trees in cold resistance. (3) *Larix*: Grafts have been made of various species of Larch on stocks of *L. decidua*, *L. leptolepis*, and *L. sibirica*, in order to study effects of the stocks on the flowering period of the scions. Nursery stock of the 1944 sowings was severely attacked in 1945 and 1946 by *Meria Laricis*: in 1945 both numbers of *L. leptolepis* in the trial were completely resistant and reached normal size for their age. In 1946 further completely resistant individuals were found in varying numbers among certain provenances of European Larch; almost all of them showed considerable vigour and proved on examination to be spontaneous hybrids between *L. decidua* and *L. leptolepis*. Artificial hybridization of these two species is being done on a rather large scale. (4) Other conifers: *Picea sitchensis* × *glauca*, produced in 1942, is proving a very fast grower at Ekebo. At Dalfors *Pinus banksiana* and *P. contorta*, planted in 1942, are doing considerably better than the Swedish *P. sylvestris* used as controls and show no frost damage; *P. resinosa* and *P. strobus* appear to have been failures. Measurements in a plantation of *P. contorta* var. *latifolia* at Grensholm are so promising that this species may have a permanent place in Swedish forestry. Among the other conifers being tried, *Pseudotsuga taxifolia* f. *caesia* is showing vigorous growth. (5) *Populus*: Research has begun at the Ekebo station on the resistance of various Aspen crosses to *Fomes igniarius*. At Sundmo grafting has proved a good method of inducing flower production in Aspen when catkins are not produced in the natural stands from which it is desired to propagate. At Dalfors *P. tremuloides* × *tremula* is showing the best height growth among the Aspens, and some individuals of

this crossing appear to be immune to fungus attack; a certain amount of frost damage, however, suggests that Dalfors is a little too far N. for this hybrid. (6) *Betula*: The first trial plantations of 1942 and 1943 are growing well and differences between the various progenies are beginning to emerge more clearly. The oldest trials of curly Birch (planted 1943) show increasing evidence of the formation of figured wood in the young stems, but differences of stem form and wood structure are occurring between individuals with the same mother tree as well as between different 'families' of individuals. A very imposing tree of *Betula verrucosa*, found at Medle, Västerbotten, is possibly a triploid. All the best 'Grey Birches' so far reconnoitred by the Sundmo branch have proved to belong to *B. verrucosa*. (7) *Alnus*: Two triploid forms have been found in the progeny of *A. glutinosa* and *A. incana* crossed with exotic species. The triploids differ markedly in growth, one being a slow- and the other a fast-growing type.

[1456]. 12.II.3 (485) : 06.I. ARNBORG, T. *Sällskapet för praktisk skogsförädling verksamhet under åren 1941-5*. [*The work of the Society for Practical Forest Tree Breeding, 1941-5*.] *Norrlands SkogsvFörb. Tidskr.* 1946 (2), (220-68). [Sw.]

An illustrated, semi-popular account of the history and activities of this Society, which has been working on the lines discussed in a recent book [see *For. Abstr.* 8 (pp. 467-71)] by its former leader, Dr. Bertil Lindquist. The present article contains brief general notes on the selection and registration of élite material, classification of stands for seed collection, establishment of nurseries, progeny trials and grading of planting stock, special trials in progress with Norway Spruce of Central European provenance, grafting and other work towards the establishment of seed orchards, timber studies, studies on forest types and regeneration, collaboration with other persons or bodies interested in tree breeding, and a final section on the forests of the individual members. The present members are 12 forest industrial companies and the Gävleborg County Forestry Board.

[1459]. 12.II.3 : 12.25 (44) : 52 : 56 : 21. FRANÇOIS, L. *Le pin sylvestre de race noble de Saint-Dié des Vosges*. [*The superior race of Scots Pine of St. Dié in the Vosges*.] *Rev. Eaux For.* 85 (5-9), 1947 (265-80; 354-73; 414-40; 465-77). [F.]

The author deals in detail with many aspects of the superior race of *Pinus sylvestris* which occurs on siliceous gravels in the neighbourhood of St. Dié, dividing it into three varieties, distinguished by different types of bark. The monograph comprises:—(1) Introduction (general considerations, history of the St. Dié stands, origin of the race, distribution). (2) Morphology and anatomy (height, diameter, and volume increment; stem form, form factor, volume tables; bark; branches; ecological factors affecting form; formation of heartwood); yield; comparison with other races of Pine. (3) Management and silviculture.

[1498]. 2 : 12.26-8 (471) : 32 : 33.15.1 : 47. APPELROTH, E. *Om björken och dess skötsel i Finland intill senaste världskrig*. [*Birch and its silviculture in Finland up to the last world war*.] *Norrlands SkogsvFörb. Tidskr.* 1946 (3), (331-90). [Sw.] LAPPI-SEPPÄLÄ, M. *Om den rationella skötseln av björkeskogar i Finland*. [*The rational silviculture of Birch-woods in Finland*.] *Tidsskr. Skogbr.* 55 (4/5), 1947 (154-64). [Sw.]

Birch, the pioneer tree species in Finland after the glacial period, has been much favoured in comparison with the longer-lived conifers by the traditional practice of felling and burning forest for temporary agriculture, which persisted—especially in E. and central districts—into the twentieth century and was not finally prohibited by law until 1928. At present, the economic limit of Birch in this country is at roughly 65° N. lat. To the S. of

this line the standing volume of Birch, according to the forest survey of 1936-8, was 204 million cu. m. over bark (19.2 per cent. of the total growing stock for all species), with an annual increment of 7.64 million cu. m. under bark (20.9 per cent. of total increment). The great rise in demand and prices for Birch that accompanied the development of the veneer and plywood industry is discussed with special reference to the concurrent increase in tolerance of lower grades of logs and the utilization of lower-grade materials for cores, &c. The defects of peeler logs are in the main remediable by good silviculture, and present log values could probably be doubled by proper tending operations. The commonest defects are knots, crooked or excentric growth, 'black rot' due to *Fomes nigricans*, and checking (often caused by the weight of snow on thicket stands, and formerly by bark-stripping, which is also responsible for patches of hard, brittle wood beneath the stripped areas). Risk of damage by black rot is always present if water can penetrate under the bark, e.g. through branch stubs or open wounds. Other fungi, and insects as a whole, are generally of minor importance, except for colour defects produced by the larvae of *Dendromyza betulae*. As the outer, later layers of wood determine quality, and rapid growth is a decisive factor, the growing of Birch as a crop should be confined to the better, moist sites, rich in nutrients. The best wood is produced in mixed Birch and Spruce of uniform growth, e.g. where the former has regenerated between Spruce seedlings and has been forced by competition to grow more slowly, thus making the best use of the Spruce's ability to aid natural cleaning of the stems. On open ground Birch regularly overtops the Spruce, which is relegated to the lower storey but will take over when the Birch is felled.

Dense Birch in the thicket stage is very susceptible to snow damage and needs early cleaning. The first thinnings must be cautious, but all whips and suppressed trees should be removed, since they react poorly to release. When natural pruning extends to a good butt length, up to 600 main crop trees per ha. (though it is seldom that so many are available) are selected for pruning (of dead branches only). A pruning team usually consists of two men, the first removing the branches within reach of a pole 2.5 m. long and the second those within reach of a 4.5 m. pole (both provided with the pruning saw devised by the Finnish Forest Research Institute), while a boy marks the trees with oil-paint. It is a great advantage if the trees are first selected and marked by trained staff. Pruning, which pays only for good trees on good sites, should be done during the period of rapid increment and preferably in summer.

After pruning, the crop trees must be heavily thinned for rapid diameter increment. Older stands that have remained closed seldom respond to heavy thinning, as Birch needs an even development to maintain good increment. Marking should be done in summer, when crown development is most readily assessed, and special attention must be paid to the quality of the stems.

The rotation is about 70 years. In mixed stands the Birch is usually ready for final fellings, and its removal provides a heavy thinning, at a time when the conifers need the additional room. Properly treated mixtures, particularly with Norway Spruce (which is the natural successor to Birch on the better sites), have advantages in both quality and outturn on the one hand and improvement of the forest microclimate and soil on the other.

Regeneration of pure Birch has been severely restricted by the prohibition of clearing and burning for agriculture, and a change of species is almost inevitable in the absence of burning. On the better sites the trend is to convert to Norway Spruce, which comes in naturally where seed is available and is planted or sown after Birch elsewhere. An admixture of Birch is welcomed and is readily obtained by suitable felling practice. Where Birch has to be planted, e.g. in groups on restricted areas, 2-year-old seedling or 3-year

transplant stock can be used. Young mixtures need careful treatment to avoid whipping and suppression of the conifers by the Birch.

As most Birch is floated to the mills, about 80 per cent. of the total cut is felled in summer, using transpiration from the intact crowns to reduce wood density sufficiently to ensure buoyancy [cf. *For. Abstr.* 9 (No. 1654)]. Trimming and crosscutting are done in late autumn, before the snows. In marking, felling, and conversion, all possible care must be taken to prevent injuries to the bark, which cause degrade.

Of the taxonomic forms concerned (*Betula verrucosa*, *B. pubescens* and intermediates), the *verrucosa* types are much the most important economically and should be favoured on good sites.

[1551]. 23.24.2 : 07.7. *New Tree Planter. Stb. Lumberm.* 175 (2195), 1947 (64).

The Lowther tree planter manufactured by the Lowther Co., of Chicago, has established a planting rate of 10,000 trees per day. Specially designed for use on cut-over land where the ground is filled with heavy roots and old stumps, it can be drawn by any type of farm tractor. It will work satisfactorily on all types of soil and on slopes of up to 30 per cent.

[1576]. 24.51. BARTH, A. *Om kunstig kvisting som middel i kvalitetsproduksjonens tjeneste.* [*Pruning as a means of producing good quality timber.*] *Tidsskr. Skogbr.* 53 (7/8), 1945 (113-41). [Nor.]

Emphasizes the importance of good pruning and gives instructions for pruning different species of trees, with suggestions for the selection of suitable trees, price tables and examples illustrating the financial advantages of pruning.

[1578]. 24.51 : 12.25 : 33.03 : 82. *Contract Pruning on the Ochoco. Timberman* 48 (12), 1947 (48).

In order to improve the pure Ponderosa Pine stands in the Ochoco National Forest, by providing peeler logs for the next cutting cycle, a contract pruning programme is being carried out. The trees to be pruned are first marked by Forest Service officers. Each contract specifies a definite number of trees in an area and carries a time limit for completing the pruning. The contractors are paid by the tree. Trees are pruned to 10 ft., in order to provide one clear 8-ft. veneer log at maturity. It was found that a man can prune three trees to 10 ft. for every one pruned to 18 ft. to produce two clear 8-ft. logs; thus pruning to the lower height produces half as much again in volume of clear timber within the limits of time and economic cost. The average man prunes about 100 trees per 8-hour day. In addition to pruning, the contractor must remove all small trees under 3 in. diameter within a radius of 3 ft. of the select tree. Foresters check the work once a month, and the contractor is paid for trees satisfactorily pruned.

[1579]. 24.51 : 07.7 : 12.25 : 46. [*Pruning of Douglas Fir.*] *Rep. B.C. For. Serv.* 1946, 1947 (19-20).

In 1942 the dominant trees in a plantation on a very good site at Green Timbers Forestry Station, B.C., were pruned to 7 ft. high in a test of tool efficiency [cf. *For. Abstr.* 5 (33)]. The study of methods was continued with a second pruning from 7 ft. to 13 ft., four years later, when the stand was in its 17th year. It was confirmed that Douglas Fir should not be pruned above half the height of the tree; some trees pruned when too small were lost. In the 1942 operation the low pruning averaged 6.4 minutes per tree (pruning and walking between trees); undergrowth is now much less dense and for the current pruning from

7 to 13 ft. by ladder and hand-saw, pruning and walking time averaged 5.6 minutes per tree, and saw-cleaning and resting took another 0.7 minutes. Pole saws were less satisfactory, in this still dense stand, than ladder and hand saw, total time per tree being 13 per cent. more. Ladders were quicker and less laborious than climbing.

A history of the rate of healing has been kept for two branches on each of 80 trees pruned to 7 ft. high. After two seasons of growth, healing was complete on both sides of 9 per cent. of the trees, and one knot was completely covered on 4 per cent.; one year later the figures were 50 and 15 per cent. respectively. Healing is most rapid on trees pruned tangentially to the bole, slightly less when the collar of bark at the base of branches is left, and much slower when pruned with shears or axes.

[1640]. 32.25.5 : 07.7. KNAPP, G. E. *The Woodpeeler. Mechaniz. Manual Stb. Pulpwood Conserv. Ass.* No. 31, 1947. pp. 2. P.R.

Describes and illustrates 2 small portable bark-removing machines: (1) a fence-post peeler built on a welded iron frame and consisting of a chain barking device which removes the inner and outer bark and, with one operator, will peel 200–350 6½-ft. Pine posts, 3–6 in. in diameter, in an 8-hour day; (2) a pole peeler, also worked on the chain barking system, which moves along the pole under its own power guided by the operator; it takes 4 or 5 trips to remove bark from all sides and 15 minutes (by operating tests) to peel all inner bark off a 45-ft. Pine pole.

[1919]. 47 : 12.25 (44) : 43 : 44.3 : 45.3 : 66. SARGOS, R. *Causes d'altération du bois de pin et nécessité d'un cahier des charges des coupes.* [Causes of deterioration of Pine timber and need for regulation of fellings.] *Rev. Bois Appl.* 2 (2), 1947 (7–11). [F.] P.R.

Discusses the effects on the Landes forests of the serious forest fires of 1942–6, the increase in fungus and insect attacks and means of combating the latter with insecticides and the introduction of insects parasitic on *Ips sexdentatus*, which causes most of the damage. Amongst other desiderata, the need for official regulation of the period and extent of fellings is emphasized.

[1996]. 97.3 (411–14) : 7. ZEISSL, S. *The Relation between Forestry and Hill Sheep-Farming.* *Scot. Agric.* 27 (2), 1947 (95–8). O.R.E.

A comparison is drawn between forestry and hill sheep-farming in Scotland in order to assess their relative contributions to the national economy. Annual receipts from hill sheep-farming, including subsidies, averaged about £1 per 'plantable acre' on some of the larger lowland farms. The corresponding forestry production may be estimated at £3 to £6 according to the species and quality. If yields are compared in percentage of invested capital, higher figures are obtained for hill sheep-farming, i.e. 9–14 per cent., as compared with 3–6 per cent. for forestry. This higher yield is due to substantial subsidies and grants. On the other hand, the much smaller capital investment and the special risks involved in sheep-farming make it necessary to assume a higher rate of compound interest. The writer has calculated 3½ per cent. for hill sheep-farming but only 2½ per cent. for forestry. A comparison of land values per acre for the two industries shows that 1 acre of land which can produce reasonably good timber is worth, under present conditions, 2 to 4 times as much for forestry as for hill sheep-farming. Forestry employs on an average 5 times as many workers per acre as hill sheep-farming, hence its importance in the resettlement of population in rural areas, where, the author suggests, both industries could be developed advantageously side by side.

France. The Poplar-planting programme is in full swing, and during 1947 10,000 land-owners obtained subsidies from the national forestry fund for the purpose of planting. Loans can be obtained at a rate of $\frac{1}{4}$ per cent. repayable in 50 years, which is very advantageous to planters. The Poplar Committee proposes to set up a Populetum at Vineuil near Blois in the Loire valley. The Committee gives two general pieces of advice to intending planters:—(1) never to plant trees coming from a region infested with canker; (2) to plant nothing but *Populus robusta* in infested areas (*Action forestier*, Paris, Dec. 1947).

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[2005]. 06.6 : 97.2. TRENK, F. B. *Timber Harvest Tracts Advance Farm Forestry*. *J. For.* 46 (1), 1948 (31-4).

The use of small publicly owned demonstration forests is recommended in areas where woodlands are, or could be, of importance in farm economy. Such a scheme in Wisconsin is described. A feature of the scheme is holding 'harvest field days' which demonstrate the harvesting of current increment and net hourly wages, instead of income per acre, which has been, in the author's opinion, too long used for appraising the productive value of farm woods.

[2024]. 09.4 (573) : 97.4. NEVZOROV, N. V. *Budushchie tsentry lesnoy promyshlennosti Vostochnoy Sibiri*. [Future centres of the forest industry of E. Siberia.] *Lesnaya Prom.* 1947 (7), (3-6). [Russ.]

Tabulates and discusses data, so far as available, for the Angara-Lena region of E. Siberia, where it is planned greatly to increase exploitation and to create forest industries at suitable centres. It is estimated that there is an area of 5.9 million ha. carrying about 1.1 milliard cu. m. of exploitable timber, in which annual fellings of 14-15 million cu. m. could be made. Over most of the area the percentage of mature and overmature stands is 50-66. The chief species, in order of exploitable supplies, are Scots Pine, Larches, Spruces, Birches, Aspen, and Siberian Pine.

Before organized exploitation can begin, further and more exact aerial and ground surveys will be necessary, followed by detailed planning for the development of the industries envisaged, with particular reference to their location and communications.

[2028]. 09.4 (73) : 98.1. DIETZ, M. A. *A Review of the Estimates of the Sawtimber Stand in the United States, 1880-1946*. *J. For.* 45 (12), 1947 (865-74).

Attempts to determine trends in timber depletion by comparing past estimates of standing timber have frequently been unsatisfactory owing to changes in standards of merchantability, of accessibility, and of accuracy in the estimates themselves. The writer reviews the several estimates, outlines the standards used, and discusses their relative reliability. The estimates of 1945 for certain regions of the U.S.A. for which comparable earlier figures are available show a 14 per cent. decline in standing sawtimber during a period of about 11 years.

[2082]. 12.11.3 : 12.25. RIGHTER, F. I. *New Perspectives in Forest Tree Breeding*. *Science* 104 (2688), 1946 (1-3). O.R.S.

The application of agricultural plant-breeding concepts to silviculture has led in the past to misconceptions. For example, the high degree of genetic uniformity required for agricultural crops is not necessary in silviculture. Interplanting to test growth rates of hybrid stock will produce stands of merchantable timber whatever the outcome of the

experiment. Either a pure stand will be obtained through the dominance of one kind of stock, or, where growth rates are equal, a mixed stand will result. In either case no commercial loss need be sustained. The author believes that the generally accepted idea, that it is impracticable to produce tree hybrids on a large scale through controlled pollination, is based largely on experiments with angiosperms. Tests conducted at the Institute of Forest Genetics, Placerville, California, have indicated that numerous interspecific coniferous hybrids can be produced in large quantities and at a reasonable cost through controlled pollination. The essentials of the breeding procedure are as follows:—Two species are crossed on a small scale. If hybrids are obtained they are tested for vigour and form against the parental species in small nursery tests for 2 or 3 years. If the results are promising, the hybrids are produced in quantity and interplanted with the common stock in the area to be reforested. The question of the succeeding crop can be examined in advance by investigating seed production and the ability of the F_2 generation to establish itself, and by testing the vigour of the F_2 generation in small nursery and plantation experiments. If results are favourable, restocking of the area is left to the F_2 population, which is subjected to natural and also (if possible) to artificial selection. If results are unfavourable the area is re-planted with the F_1 hybrid, or, perhaps, with a back-cross of one of the parental species and the hybrid.

[2162]. 23.22.1 : 07.7 (492). HOUTZAGERS, G. *Mechanisatie in de bosbouw: de economische en bosbouwkundige zijde van het vraagstuk*. [*Mechanization in forestry: the economic and silvicultural aspects of the problem.*] *Ned. Boschb.-Tijdschr.* 19 (12), 1947 (337–42) [Du.]

From an investigation of the production cost of Scots Pine in Holland [see *For. Abstr.* 9 (No. 1961)] it is inferred that f. 200–250 per ha. is the maximum that can be spent on site preparation for this species, and that even with the subsidy of 50 per cent. of costs for such work [see *For. Abstr.* 8 (p. 462)] it will be uneconomic to use manual labour unless timber prices rise. Stump clearing costs f. 150–200 per ha., leaving little for cultivation if a subsidy is not obtained. With the subsidy, which can be claimed for most of the land needing artificial regeneration, the maximum that can be spent on site preparation becomes f. 400–450. For Larch, Douglas Fir and mixed forest, yields may be higher, but the higher initial costs should not be overlooked. The Forest Service estimates the costs per ha. for planting and beating up as respectively f. 930, f. 1175 and f. 920, as compared with f. 470 for direct sowing, f. 505 for planting of 1/0 and f. 605 for that of 2/0 Scots Pine. Costs of site preparation should therefore not exceed those for the last-named species.

The chief points made as regards mechanical cultivation are that: (1) A radical distinction must be drawn between soils needing deep cultivation and those where shallow working will suffice. Most of the deforested areas are of the latter type. (2) The best mechanical cultivation is that which secures maximum activation of the humus by mixing it intimately with the mineral soil. This would also favour the use of direct sowing, which is believed to be superior to planting from both silvicultural and economic points of view.

Standard figures for the costs and advantages of any particular form of mechanical cultivation are not and may never be available, since combinations of soil type, ground cover, and obstacles are so numerous that each case has to be considered on its merits.

[2171]. 23.23.13 : 12.25 : 07.7. DELEVOY, G. *Le désailage des graines de résineux*. [*De-winging of Conifer Seed.*] *Bull. Soc. for. Belg.* 52 (9/10), 1947 (124–8 + plate). [F.]

Describes a pneumatic seed de-winging machine, designed and used at the Groenendael Research Station, which is easy to operate and causes a minimum of damage to the seeds.

Its average output per hour, in kg. of extracted seed, is Scots Pine 4-5, Spruce 3-4, and Douglas Fir 2-5.

- [2172]. 23.23.15. MILLER, P. W., and McWHORTER, F. P. *The Use of Vapor-heat as a Practical Means of disinfecting Seeds*. *Phytopathology* 38 (2), 1948 (89-101). [U.S. Bureau of Plant Industry.]

A method for disinfecting seeds by vapour-heat is described, using seeds of a number of vegetables. The data presented indicate that certain fungi are killed at relatively low vapour-heat temperatures for short exposures. Most bacteria, however, are not killed by vapour-heat treatments that are safe for seeds, and the control of bacterial seed-borne diseases by vapour-heat alone seems impracticable. Certain kinds of seeds will apparently endure considerably higher vapour-heat temperatures than are required to kill all associated fungi. The important advantages of vapour-heat treatment are (a) temperature control is not critical as for hot-water treatment, (b) treatment periods are short in comparison with dry heat, and (c) the difficulty of drying seed, which limits the use of hot water, is eliminated by proper vapour-heat procedures. *From authors' summary.*

- [2176]. 23.23.19. *Proposal of Rules for the International Control of Forest Seed*. [International Union of Forest Research Organizations, Stockholm.] [1947?] pp. 39.

Proposals for international rules for seed testing, under the following headings:—selection of samples, estimating the appearance of the seed, testing the purity of the seed, determination of the germinative capacity, determination of germination speed, reserve methods for germination tests, percentage of germination in the field, determining the weight of 1,000 seeds, determining the water content, determination of the amount of seed in cones, test tolerance, evaluation and test report.

- [2180]. 23.24.2 : 07.7. *New Pacific Northwest Planting Hoe*. *W. Cst. Lumberm.* 74 (12), 1947 (80). Also in *Timberman* 49 (2), 1947 (128-9).

Description, with photographs, of a standardized planting hoe developed as a result of co-operative action by private foresters, the Oregon and Washington State Forestry departments, and the U.S. Forest Service. The blade is $\frac{1}{4}$ in. thick, $3\frac{1}{2}$ in. wide at the heel, $3\frac{1}{4}$ in. wide at the point, 10 in. long from point to inside of eye. The eye is rectangular and there is a reinforcing gusset between the inside of the eye and the blade. The eye is cast in one piece with the blade, which is polished and annealed. Weight of blade is almost 4 lb.; with handle the tool weighs about 6 lb.

- [2202]. 23.61 (410). JAMES, N. D. G. *Weeding Plantations*. *J. Land Agents' Soc.* 47 (1), 1948 (11-12).

Weeding costs in Britain in 1947 appear to be £4-£6 per acre for the first year after planting. Suggestions are made for reducing costs. In young plantations, Hazel rods may be put along the lines as markers and weeding confined to a 2-ft. lane; the danger that the uncut weed growth may collapse over the lines must be watched. Time and labour may be further saved by cutting small areas around individual trees sufficient to release the leading shoot. Finally, the use of some mechanical method such as the motor scythe is considered. Fitting a 3-ft. knife will give a sufficient margin of safety for tree rows 5 ft. apart; the chief drawback is the risk of fouling old stumps, &c.

- [2291]. 31.8 : 12.25 : 64. PAUL, B. H. *Lumber Grades vs. Site Quality of Second-growth Douglas Fir. W. Cst. Lumberm.* 74 (11), 1947 (73, 75, 96).

A preliminary report on a joint study undertaken by the Forest Products Laboratory, Madison, and the Pacific Northwest Forest Experiment Station on the quality of second-growth Douglas Fir. The two forest areas selected for the study were respectively site quality II and site quality IV for Douglas Fir. The dominant trees of the 100-year-old site II stand averaged 170 ft. in height and 36 in. d.b.h., with stand density 200 to the acre. In the 150-year-old site IV stand the corresponding figures were 125 ft., 30 in., and 400 trees to the acre. The slow growth during the past 20 years indicated that both stands were overstocked. In both, the trees had not yet completely rid themselves of dead branches, but branches on site II trees were considerably larger. While the greater height and diameter for a given age of the trees of site II reflect the higher productivity of that area, it was found that lumber from typical logs from that site graded lower on the average than lumber from logs from site IV, the main factor involved being the condition of knots. The larger trees cut from site II contained not only larger knots, but a higher percentage of lumber with loose knots. After kiln drying, only 35 per cent. of the lumber from site II was graded No. 1 or better, compared with 69 per cent. of that from site IV. On the other hand, the total yield per acre per year of all grades on site IV would be only about half that of site II. In both stands it was clear that lumber free from knots was practically unobtainable in rotations of less than 100 years. Close stocking, pruning of side branches, and regular thinning are indicated as means of obtaining high-grade lumber; and once these conditions are fulfilled, the benefits of site quality will begin to tell.

- [2292]. 31.8 : 12.26-8 : 31.27 : 32.81. PAUL, B. H. *Guides for the Selection of Tough Hickory. Rep. U.S. For. Prod. Lab., Madison* No. R1683, 1947. pp. 5 + 1 plate. P.R.

Discusses methods of selecting Hickory in the stand, from the stand character and history, the quality of the site, and the appearance of individual trees, and of judging the quality of lumber from ring width and weight.

- [2310]. 32.29.1 : 12.25. *Destroying Stumps by Charpitting. Ext. Serv. Bull. Wash. St. Coll. Agric.* No. 344, 1946. pp. 11.

'Charpitting' is a cheap method of destroying large coniferous stumps by fire, without the use of explosives or expensive equipment. The stumps are burned far below plough depth by a process similar to that used in making charcoal. From two to eight weeks are required to charpit a large stump. The requisites are a clay soil, coniferous stumps, an experienced operator, dry wood for starting fires, and systematic attention to the fires. The advantages of the method are that it is cheap and safe, that it leaves the ground in good condition for making a seedbed or planting, does little injury to the soil round the stump, allows pasturage while the charpitting is being done, and that crops grow vigorously where stumps have been burned.

- [2311]. 32.3 : 12.25 : 76 : 35. BOND, W. E. *More Dollars from Integrated Utilization. Stb. Lumberm.* 175 (2201), 1947 (220-2).

Yields and stumpage returns of different categories of products cut at various ages from a Slash Pine plantation are given. Of the trees removed in each period and also in the final cutting, as many as are suitable should be sold for posts or poles. The rest can be marketed

as sawlogs or pulpwood according to their suitability. This method of integrated utilization will bring the owner almost 5 times the income he would receive from selling pulpwood stumpage alone, and more than $1\frac{1}{2}$ times that which he would receive from just sawlog and pulpwood stumpage.

[2424]. 33.36.1 : 33.31 : 33.52. *German Wood Preservative Substitute. Chem. Industr.* 58 (6), 1946 (1046-7). L.S.

'Flunax', a wood preservative used by the Germans during the war as a substitute for creosote in treating railway sleepers, consisted of 84 per cent. sodium fluoride, 8 per cent. xylenol and 8 per cent. caustic soda.

[2456]. 33.52 : 33.36.1 : 76.1. RIJN, J. VAN. *Sleepers: (a) Different Types; (b) Maintenance Methods; (c) Financial Comparisons. Special Report. Mon. Bull. int. Rly. Congr. Ass. (Engl. Ed.)* 24 (4), 1947 (481-6). L.M.S. through D.S.I.R.

Summarizes reports made to the fourteenth session of the International Railway Congress Association, 1947, based on replies to questionnaires addressed to the railways of (a) America, Great Britain, India, Dominions, Protectorates and Colonies, China and Egypt and (b) Belgium and colony, Bulgaria, Denmark, Spain, Finland, France and colonies, Greece, Hungary, Italy, Luxembourg, Norway, Netherlands and colonies, Poland, Portugal and colonies, Rumania, Sweden, Switzerland, Czechoslovakia, Turkey, and Yugoslavia. Conclusions reached are that wooden sleepers, both hardwood and softwood, are by far the most widely used, that metal sleepers are preferable for the tropics, and concrete sleepers, though some types give good results, little used. In spite of initial lower costs, a softwood sleeper costs more per year of service than a hardwood one. Leaving aside countries rich in timber, the cost of impregnating sleepers is made good by their longer life. In steel-producing countries metal sleepers may compete in cost with wooden ones, and, though no definite figures are available, the annual cost of concrete sleepers, given careful manufacture and suitable methods of fastening, may be lower than either.

[2525]. 43.02 : 07.7. HIGGINS, H. G. *A Note on the Assessment of Bush Fire Hazard with a suggested design for a Simple 'Hazard Meter'.* Repr. from *J. Coun. sci. industr. Res. Aust.* 19 (3), 1946 (293-4). Repr. For. Prod. Aust. No. 91.

A type of wood hygrometer is described and illustrated, consisting of a strip of 2-ply wood attached at one end so that any bending can be observed on a dial face. The veneer with the grain parallel to the length of the strip is very thin; the other, with the grain at right-angles, is much thicker. An elastic sealer is applied to the edges. The construction provides for a large movement of the indicator end of the strip along with a relatively slow rate of response to moisture changes; hence the apparatus should indicate changes in moisture content corresponding to those of small twigs in the forest.

[2541]. 44.3 : 12.25 : 12.21 (676). NATTRASS, R. M., and CICCARONE, A. *Monochaetia canker of Cupressus in Kenya. Emp. For. Rev.* 26 (2), 1947 (289-90 + plates).

A canker disease of *Cupressus macrocarpa* in Kenya, caused by *Monochaetia unicornis* (Cooke and Ellis) Sacc., is compared with a disease on the same host in California caused by *Coryneum cardinale* Wagener, and the similarity of the two diseases noted. The disease in Kenya appears to be confined to the highlands east of the Rift Valley. *Author's summary.*

[2570]. 45:12 : 45:2. KALMBACH, E. R. *Advances in Rodent Control. Yearb. Agric. U.S. Dep. Agric. 1943-7. 1947* (890-6). O.R.E.

Compound 1080, or sodium fluoroacetate, has proved toxic to all forms of life on which it has been tested and is an effective poison for the control of all types of rats, mice, squirrels, and prairie-dogs. Highly soluble in cold water, it was first employed in the control of field rodents in Oct. 1944, proving signally successful against California ground squirrels. Its performance in the control of these and other field rodents has rarely been equalled, and, if baits prepared with it are protected by colour, it appears to be a reasonably safe poison from the point of view of bird mortality. The great objection to its use is its high toxicity to mammals, including domestic cats and dogs.

A rabbit-repellent paint known as '96a' combines copper carbonate, copper sulphate, and dry lime sulphur as the active agents, with a synthetic resin and asphalt emulsion dissolved in ethylene dichloride as the adhesive. When applied to the bark of dormant trees, '96a' is effective in preventing damage by rabbits.

To make poisoned grain baits less dangerous to seed-eating birds, use is now being made of the fact that birds perceive and react to colour whereas rodents are almost completely colour-blind. Colours most effectively deterrent appear to be those near the centre of the humanly visible spectrum, the yellow and green bands.

[2631]. 64 : 56. [DAY, W. R.] *Problems of Soil and Land Classification. Nature, Lond.* 160 (4072), 1947 (686-7). [Imperial Forestry Institute, Oxford.]

A summary account of papers and discussions at the first conference of the British Society of Soil Science. W. R. Day discussed criteria for judging the economic value of land for forestry. If the tree is to come to a proper height at maturity or at a given age, there is an optimum curve relating its rate of growth with age, for each species in a region. Any falling off from this curve is due to some soil factor making the site less suited for the economic exploitation of that species. An illustration is the rate of growth of forest on thin or wet land, often considered suitable for forestry because unsuitable for agriculture. In these conditions growth of many species, though initially rapid, is too slow for economic exploitation.

CANADA. Recognizing the serious threat to the national economy in the destruction of Canadian forests by insect pests and the shortage of trained investigators in the field, the 4 leading forest-industries' associations (B.C. Lumber Manufacturers' Ass., B.C. Loggers' Ass., Canadian Pulp and Paper Ass., and Canadian Lumbermen's Ass.) have combined to endow 4 entomological scholarships of \$200 per annum for 4 years each, to be awarded to registered students at the Universities of New Brunswick, Toronto, Laval and British Columbia (*British Columbia Lumberman*, Vancouver, Dec. 1947).

The production of roofing shingles from Saskatchewan Balsam Fir is now under consideration and initial experiments have been very successful. They could be produced at only half the cost of British Columbia Cedar shingles (*Timber of Canada*, Ottawa; Jan. 1948).

SWEDEN. A 'calculating machine' for determining the growth of forest trees was shown at a recent Forest Week Exhibition at Stockholm. It is used for counting the number of annual growth rings of the increment cores obtained during forest surveys by the Swedish Department of Forestry. By an ingenious combination of the microscope's feeding device and a calculating machine of a slightly modified type, the thickness of annual growth rings in the wood is registered simultaneously with the number of rings. It is possible to examine 500 cores an hour (*Timber Trades Journal*, London, 17.4.48).

THE LATE DR. M. C. RAYNER

THE tragically sudden death on 17th December 1948 of Dr. M. C. Rayner has robbed the world of science in general and of British forestry in particular of one of the foremost workers in the narrow field of mycorrhizal research.

For some years head of the Botany Department of Reading University, Dr. Rayner had a distinguished academic career, graduating B.Sc. with first-class honours in Botany at London University in 1908 and D.Sc. in 1915. The latter distinction was earned by a brilliant piece of research in which she showed that in the common heather (*Calluna*) the mycelium of the mycorrhizal fungus invades the tissues of the immature seed, thus ensuring that the fungus is available to infect the rootlets of the developing seedlings. This was the first record of this phenomenon, though other cases have since been found.

In 1927 Dr. Rayner published a general book with the title *Mycorrhiza*, which summarized the then existing knowledge on the subject. A year or two later Professor H. M. Steven, who was then Forestry Commission Research Officer for England and Wales, brought to Dr. Rayner's notice the very indifferent results obtained by the Forestry Commission in their attempt to afforest part of Wareham Heath in Dorset by direct sowing with seed of *Pinus pinaster* Ait. and other species of pine. Dr. Rayner visited Wareham and was at once attracted by the area itself, as well as by the nature of the problem which appealed strongly to her as a means of putting to a practical end the specialized knowledge she had already acquired. There then began that long and patient series of investigations at Wareham with which the name of Dr. Rayner will always be associated.

From 1930 onwards Dr. Rayner was the recipient of a grant from the Forestry Commission to assist her in her researches, which, though starting and in general concentrated at Wareham, covered a considerably wider field and led to frequent visits to other parts of the country. The grant covered only actual out-of-pocket expenses, as Dr. Rayner consistently refused to accept any personal emolument which would have restricted in some measure her freedom to travel or to accept other work not directly connected with the problems of the Forestry Commission. She did, in fact, travel extensively abroad, visiting many forests and nurseries in the U.S.A. and elsewhere. These visits did much to enlarge her grasp of the problem of tree mycorrhiza and to convince her of its great practical significance.

The Wareham researches were published in *Forestry* over a series of years and finally brought together and republished with the addition of a paper by her husband, Professor W. Neilson Jones, in a volume entitled *Problems in Tree Nutrition* (Faber & Faber, 1944).

Dr. Rayner later published an admirable semi-popular account of tree mycorrhiza in a little book called *Trees and Toadstools*. She also contributed numerous articles to botanical and other journals.¹

'Dr. Rayner's researches on the mycorrhizal habit in trees were based on the conception that the soil is a dynamic system and that changes in its ecological equilibrium greatly influence the soil population and react directly or indirectly on tree growth. Thus in order to produce and maintain the woodland conditions favourable to the health and vigour of forest trees, a certain ecological unit of soil vegetation must be established, so as to stimulate root activity and give rise to mycorrhizal associations.

¹ The section which follows has been kindly contributed by Dr. Rayner's colleague and assistant, Dr. I. Levisohn, to whom the writer of this notice is greatly indebted.

'Much evidence was collected by Rayner to support the view that normal behaviour of the roots of mycorrhiza-forming trees (and mycorrhiza-forming plants in general) supplies a valuable index of the health of the host plant, and at the same time of the biological equilibrium in the soil. Deviation from the normal behaviour, i.e. irregular and reduced mycorrhizal activity and structural changes in the mycorrhiza, are indications of unfavourable changes in the ecology of the soil population.

'Up to the time of Rayner's classical researches, not many details were known about the higher soil fungi, in so far as they operate directly as ecological factors; and knowledge of the behaviour of mycelia that form associations with trees under natural conditions was scarce. It is characteristic and significant of Rayner's mycorrhizal investigations that her experiments were carried out in the field, and checked in pot-cultures with transported soil from the experimental area. Only for further detailed analyses of the results were cultures with sand or sterilized soil used. The pot-culture practice proved to be indispensable as a check on the field experiments, in cases where humus or soil inocula were used that carried risks of introducing mycelial species or strains harmless to tree growth under native conditions but deleterious when introduced to a different soil environment (cf. results of introducing soil from a native stand of Norway spruce (*Picea abies* Karst.) in Sweden into the experimental area at Wareham).

'Great importance was attached to examination and re-examination of root conditions at regular intervals, as certain root infections difficult to diagnose exhibit characteristic structures only at limited seasonal periods.

'In the course of her mycological laboratory work Rayner was successful in isolating and identifying many true mycorrhiza-formers, also a number of pseudomycorrhizal mycelia, some of them previously unknown, others described but not grown in pure culture. Some of these pseudomycorrhizal (e.g. *Rhizoctonia* spp.) fungi were found to be widespread and to be particularly active in old tree nurseries, where they induced characteristic symptoms of parasitic or quasi-parasitic activity in long and short roots of pines and spruces (in the absence of true mycorrhiza-formers). Dr. Rayner collected evidence of the protective function of well-established mycorrhizal associations against attacks by these pseudomycorrhizal mycelia. This knowledge was carried over into practical application by activating the mycorrhizal mycelium present in a particular soil through specific cultural field methods, or in cases where a certain desirable fungus was absent, by introducing such appropriate mycorrhiza-former into the soil.

'In this respect Sitka spruce (*Picea sitchensis* Carr.) and Norway spruce at the Wareham experimental area received special attention. In the Wareham soil, the mycorrhizal fungus present, *Boletus bovinus* (L.) Fr., proved to act less efficiently for the two species in question than for species of pine, giving rise to associations of a 'feeble' kind. By introducing effective mycorrhiza-formers (*Rhizopogon luteolus* Fr. and *Amanita muscaria* (L.) Fr., respectively), Rayner succeeded in raising healthy seedlings supplied with a profuse mycorrhizal equipment in the first season of growth, in contrast to the behaviour of *B. bovinus* (L.) Fr. which in this particular soil is very slow in forming mycorrhiza with the spruces.

'For a number of trees with the endotrophic type of infection, whose mycorrhizal associates have resisted isolation hitherto and whose systematic affinities are not known yet, a new method of inoculation was adopted by introducing into the soil active mycorrhizal root material of the species from a vigorously growing tree whose mycorrhizal association had been studied.

'As to the theory of the mechanism and functioning of mycorrhizal association, Rayner had recently started a new line of investigation, the results of which indicate the extremely

significant fact that the stimulus to root as well as to shoot growth is not infrequently antecedent to mycorrhiza-formation.¹

On the more strictly applied side Dr. Rayner was the pioneer in the application of organic composts to raw heathland soils for the purpose of raising tree seedlings; she was also an expert in their manufacture. Her C5 compost, prepared by composting raw hops with dried blood, has acquired fame in the course of years and will long be remembered. The remarkable response made by tree seedlings raised on compost-treated raw soils was regarded by Rayner primarily as evidence for the biological inactivity of such soils in their natural state. She considered that the function of the compost was to provide the means of setting biological processes in motion which enabled the mycorrhizal fungi present in the soil to develop and form normal associations with the tree roots. When this was achieved, normal optimum growth would result and the plants would develop well even on very poor soil.

While she recognized, and would always admit when the point was pressed, that some of her composts contained appreciable quantities of nutrients, and that these were partly responsible for the results achieved, her conviction of the overwhelming importance of the biological action of the composts made her disposed at times to give too little weight to the purely chemical aspects of nutrition; and she was apt to be a trifle impatient when she felt that the 'N.P.K.' angle was unduly stressed.

However that may be, Dr. Rayner's compost experiments at Wareham have had profound and far-reaching effects on our large-scale nursery practice. The development of the compost-manured heathland nursery, which has caught on so rapidly during the last two years and which appears likely to revolutionize the raising of our nursery stocks, is a direct outcome of Dr. Rayner's pioneer researches.

It would be a mistake, however, to conclude that Dr. Rayner's contribution to the practice of raising tree seedlings began and ended with her compost technique. For some years past she had directed the management of a small nursery, called Sugar Hill, on Wareham Heath. It is true that compost manuring formed the nutritional basis of her nursery practice, but there were also some interesting and more or less novel forms of technique to which Dr. Rayner attached great importance. Among these may be mentioned:

- (1) Deep cultivation (achieved by bastard trenching) coupled with the minimum possible disturbance of the upper layer of the soil, once the compost has been forked into the top 4 inches.
- (2) Permanent areas for seed-beds. This links up with (1) because transplant lines inevitably involve considerable disturbance of the soil.
- (3) Periodic resting of the seed-bed area (every 3rd or 4th year). Compost is applied usually at the rate of 5 lb. per square yard and a soiling crop sown (lupins or mashlam mixture). The soiling crop is dug in as superficially as possible, and the soil covered with a 4-inch layer of bracken or straw over the winter. The bracken is removed in the spring and the beds resown with tree seeds.

The above technique has been in force since about 1942 and has been conspicuously successful, so that Sugar Hill research nursery has been a Mecca for visiting foresters and scientists, both from home and abroad.

Dr. Rayner had a complex but outstandingly forceful personality; a strain of combativeness made her at times a doughty opponent in controversy. She held her opinions with great tenacity, but those who were privileged to know her well appreciated her essential

¹ End of section contributed by Dr. Levisohn.

kindliness, as well as her highly cultured mind and complete devotion to her scientific work. Dr. Rayner's mental processes were quite exceptionally rapid; steeped as she was in her subject, a long session with her on the complexities of mycorrhiza was a most stimulating, though apt to be an exhausting, experience. Physically she was unusually strong until an unfortunate attack of influenza early in the nineteen-thirties, caught on one of her frequent visits to Wareham, resulted in a form of asthma which persisted and was a serious handicap to her in later life. About a year ago Dr. Rayner was involved in a motoring accident from which she never fully recovered. She and Professor Neilson Jones were due to leave England early in the New Year for a visit to Ceylon, connected with the tea plantations, but made a short farewell trip to Wareham to give final instructions for the treatment of the research nursery there during Dr. Rayner's absence. It was on this last visit to her beloved Wareham that, while resting in the hotel before dinner, she passed peacefully away. In Dr. Rayner botanical science and British forestry have lost an outstanding personality and a devoted servant.

W. H. GUILLEBAUD

THE LATE MR. RAY BOURNE, M.A.

By the death of Mr. Ray Bourne on the 30th November 1948, forestry in Britain has lost one of its most original and constructive thinkers, and many members of this Society a valued colleague and friend.

Bourne left the Indian Forest Service in 1922 to join the staff of the School of Forestry at Oxford. There he taught Forest Management and Forest Mensuration. At this stage in his professional pilgrimage his views on management were entirely orthodox. One of his duties was to take practical courses on the Continent, and it was at this period that he laid the foundations of his intimate knowledge of the forestry and foresters of Europe. In the twenties at Oxford interest was developing in ecology and soil science in relation to forestry, and Bourne was attracted to these developments. This led to his important work on locality assessment, which in turn was the basis of the distinctive type of silviculture and management which he evolved and practised in recent years in many private woodlands in England.

In 1931 he published his Oxford Forestry Memoir on *Regional Survey*. In the introduction he said 'the writer has gradually been driven to the conclusion that the determination of the correct methods of stocktaking forms the problem of primary importance in the forests of the British Empire'. As a contribution to the solution of this problem he carried out a detailed aerial and ground survey in a strip, 55 miles long, from Burford to Crowthorne, and the results and implications of this pioneer effort are set out in the publication referred to. He later applied similar methods in Rhodesia. This may be termed the imperial phase of his work, in distinction from the Indian and English phases; but it had an important influence on the last named in that it led him to the view that to practise silviculture and management effectively one must have a most detailed knowledge of the site, not only as it is to-day, but as it has been in the past. For the areas he had known longest, such as part of the Chilterns, his knowledge of the site factors was astonishingly detailed and exhaustive.

In 1937 Bourne left Oxford and started as a Private Forestry Consultant, and he rapidly built up a large practice which in recent years extended to all parts of England. He brought to this work unrivalled professional knowledge and strong convictions. First, there was his intense belief in the importance of most detailed knowledge of the site factors, already referred to, and his ability to assess such factors. Secondly, from his earlier continental experience he had a firm belief in the greater efficiency of irregular, compared with regular,

stands, and the superiority of the modern selection system as practised particularly in Switzerland. Thirdly, he held the view that natural regeneration gave better woods and timber than artificially formed plantations; and particularly since the war that it was cheaper so to restock one's woods. Finally, in recent years he attached importance to what he termed 'Mixed Forestry', following the ideas of Stephanie and others, by which was meant not forcing whole woods or forests into a particular mould, but here an irregular structure, treated on the Selection System, here a regular stand or part of a stand on the Uniform System, all as best fitted. Most of these views may be considered traditional for the professionally trained forester, but Bourne took them and applied them to the conditions he found in English woodlands and to the economic pattern of the time. Further, he developed a novel form of management to give scope for what may be termed silvicultural opportunism, founded on these ideas, but within a framework of yield regulation, based on a method of periodical and intensive stocktaking, derived from Biolley. He succeeded in this difficult work. He took neglected and semi-devastated woodlands, extracted revenue from them, filled them with natural regeneration, and progressively improved the growing stock in volume and still more in value. It was a highly personal form of management, and he appreciated the point of the criticism that it would be much more difficult for a successor to take over such work than if it had been organized on more orthodox lines. He had disciples, however, whom he gladly trained in his ways of working. If they carry on his ideas and work, the tragedy of his premature death will be softened, in the professional sense.

No appreciation of Bourne's work would be complete without reference to his interest in students and teaching. Particularly in his earlier days, Bourne did not have facility in conveying his ideas to others, either by the spoken or written word, and it cannot be said that he was a good teacher in the classroom. Those who went on Oxford tours with him, however, will remember what a force he was in the field, both mentally and physically. In recent years he took great pleasure in expounding his views and methods to Aberdeen and Oxford students in the Chilterns. In order to provoke discussion he often over-emphasized his heterodoxy and was delighted if a student picked holes in his arguments. Particularly to the student at the end of his course, he was an education in himself; he is irreplaceable in this role.

Thus has passed one of the few great foresters of our time in this country. His ideas will live on, because, apart from his written words, many who revisit the scenes of his activities will not only see the results of his work but still hear his words of counsel. To those who knew him, his personal qualities will continue to be an inspiration: his boundless energy, his almost unlimited capacity for work, and his high courage. Members of this Society will not soon forget that by his courage and the force of his will he led its Excursion last autumn in weakness of flesh but strength of spirit. He served forestry to the end.

H. M. STEVEN

REVIEWS

A Handbook of Coniferae including Ginkgoaceae. By W. DALLIMORE and A. BRUCE JACKSON. 682 pp. Edward Arnold & Co., London. Price £2. 10s.

Review by F. K. MAKINS

A THIRD edition of this well-known work appeared in 1948 and will be welcomed by everyone interested in conifers.

It begins with an Introduction, of which the first 15 pages are taken up with an outline of the morphology of conifers and their propagation and cultivation, the remainder including a synopsis of families and tribes, a key to the genera in cultivation, and reasons for name changes.

But the main purpose is to enable the species of Ginkgoales and Coniferales to be identified by gardeners, foresters, and students, rather than botanists. Besides the 120 excellent line drawings by Miss G. Lister, F.L.S., which appeared in former editions, there are 40 full-page photographs.

Practically every species of conifer is described, including those not hardy in Britain, but the latter are not included in the keys. For foresters interest centres in the family Pinaceae, especially the cypress and thuya tribes, and the Abietineae, covering *Pinus*, *Picea*, *Abies*, *Pseudotsuga*, *Tsuga*, *Cedrus*, and *Larix*, among others.

If, for instance, it is desired to determine a specimen of the Himalayan Blue Pine, usually known as *Pinus excelsa* Wallich but renamed *Pinus wallichiana* by A. B. Jackson, it can be referred at once to Section I by virtue of its leaves being needle-like or linear, in clusters or whorls: and then under Section I to *Pinus* owing to the leaves being not more than five in a cluster, at least 2-5 cm. long, with the characteristic resin canals of *Pinus*. The leaves being in fives, the leaf-sheaths deciduous, and the young shoots glabrous, reduces the choice to one of the four following species: *P. wallichiana*, *P. armandi*, *P. amamiana*, and *P. peuce*. Weymouth pine (*P. strobus*) and western white pine (*P. monticola*), with which the amateur is most likely to confuse the specimen, have minutely pubescent young shoots and are therefore ruled out. *P. amamiana* and *P. peuce* have much shorter needles, so the choice is reduced to *P. wallichiana* and *P. armandi*. Here the key enters into obscure details which may puzzle the amateur and even the expert botanist; so it is as well to turn to the description, where we read '*P. armandi* closely resembles *P. wallichiana* in foliage but the distinct bend near the base of the leaf is characteristic of the former. The young shoots of *P. armandi* are usually more or less covered with fine glands, which are not present in *P. wallichiana*. The cones of the two species are quite distinct, those of *P. armandi* being much stouter and with the scales wider than those of *P. wallichiana*'. To anyone acquainted with the two species, however, the bright green of *P. armandi* is unmistakable. There is no illustration of *P. armandi*, but there are good ones of *P. wallichiana*, *P. monticola*, and *P. strobus*, as well as other five-needled pines, so that the amateur, given patience, should encounter no unsurmountable difficulty. The reviewer has tested many of the keys on his own specimens and found them as fool-proof as it is possible to make any artificial key.

The descriptions of the better-known species include interesting notes on cultivation, both as specimen trees and forest crops, and the diseases to which they are liable.

There is an excellent index and a good bibliography.

Road to Survival. By WILLIAM VOGT. London, Victor Gollancz, Ltd., 1948.

Price 15s.

Our Plundered Planet. By FAIRFIELD OSBORN. London, Faber & Faber, Ltd., 1948. Price 10s. 6d.

Review by G. V. JACKS

BOTH these books deal, in a rather alarmist fashion, with the problems presented by, and the consequences of, a continuing increase in world population. The prospect of the global population overtaking and outrunning the global food-supply may be alarming, but not so alarming as would be the prospect of a general decrease in world population. Mr. Vogt calls upon Britain and Italy to set a shining example to the world by instituting birth control on a grand scale, yet it is only a few years since Britons were being exhorted to produce all the children that they could, not only so as to maintain their country's political position, but also from fear that Nature might fill the void created by empty cradles—in other words, from fear that with a falling population men might begin to lose their absolute command of their environment.

This is the real dilemma which neither author faces up to—whether to recognize that the criterion of ecological success and of successful adaptation to environment is the maximum population, rather than the optimum for the individual man, tree, or microbe, or to aim at the optimum, which is far below the maximum, in the hope (belied by all history) that this can be achieved without losing control of the environment. Mr. Vogt believes that the ultimate goal of mankind—an American Standard of Living for all—can be achieved only by internationalized contraception, combined with the utmost conservation of the earth's natural resources. Mr. Osborn urges, as forcefully as Mr. Vogt, the conservation of natural resources, but not the deliberate limitation of population, though he also believes that pressure of population is a main cause of the current wasteful expenditure of natural resources. Yet the reckless squandering of resources has progressed farther and faster in the United States and other thinly populated countries than in densely populated countries like India, Java, Japan, or Britain. This kind of squandermania which, if continued, might seriously threaten man's ecological dominance, seems, in fact, to be associated far more closely with the striving after and attainment of the American Standard of Living that Mr. Vogt hopes will be enjoyed by the favoured few who escape the contraceptives. Nobody will question the imperative necessity of conserving natural resources, but ecologists at least should not imagine that, when that has all been done, the individual's share of the earth's riches will be any greater; there will merely be more individuals. Contraception, sterilization, and atomic bombs will all be equally ineffective in keeping down the earth's population if its productivity increases. Most people in this world have always existed near the subsistence line—equally when there were two million or two thousand million—as also do most plants in a forest. The outlook for forests would be bad indeed if each tree were limited to producing two seeds to ensure that none of the next generation should go short of light, water, and food.

The sensational style in which these books are written should be very effective in bringing home to the public, particularly in the United States, the urgency of the question of integrated conservation of resources. Both writers regard Britain as among the first of the nations that will starve—and not without reason, if there is going to be any starvation. If the land were really put to it it could produce far more than at present. These books, though often tendentious and lacking objectivity, put the problem which we shall face and Nature will solve, if not in correct perspective, at least in a fascinating and melodramatic way.

NOTICES

Fire Control Notes, Vol. 10, No. 1. January 1949. Forest Service, U.S. Dept. of Agriculture, Washington.

EVERY issue of this excellent little periodical describes fire-protection gadgets and machines which one longs to try out or to adapt for operation in our own forests, and one admires the go-ahead manner in which the U.S. forest fire staffs develop, test, and publicize their inventions for the benefit of their Service.

The two items which attract me most in the January issue are the Spiral Rotor Trencher and the Propane-Diesel Flame Thrower, which together would appear to be an excellent 'team' for boundary fire tracing. The former is not unlike our Rotary Hoe, excepting that the revolving blade comprises a pair of horizontal spiral worm blades, rotating in the reverse direction to that of the driving wheels. It spews out a fire trace about 22 inches wide and banks the churned-up soil over a further 7 inches width on each side. Very stony and heavy soil can be tackled, but it climbs over buried boulders, roots, &c.

The Propane-Diesel Flame Thrower in trailer form comprises 48-gallon tanks for each of the two fuels. The propane would normally last for 4 to 5 days and the diesel for one day's burning. The mixture gives a flame of intense heat. A smaller back-pack type has also been produced for use on terrain where the trailer cannot be used. G. B. R.

Solid and Laminated Wood Bending. By W. C. STEVENS and N. TURNER. Forest Products Research Laboratory, Princes Risborough, Dept. of Scientific and Industrial Research. H.M. Stationery Office, 1948. 5s.

THE authors have compiled a thoroughly practical handbook on a very interesting subject, around which unnecessary mystery has been wrapped in the past, and about which little has been published. The book meets a great need in factories making furniture, sports goods, aircraft, boats, and other products involving bent wood. There are 26 photographs and 44 figures. The theory as well as the practice of bending is dealt with.

Oxford University Forest Society Journal, 1948. (Obtainable at Dept. of Forestry, Oxford. Price 5s.)

THE O.U.F.S. Journal for 1948 contains at least two articles of major interest to the general run of foresters in Great Britain.

In the article on 'The Future of Private Estate Forestry in Britain' Mr. C. P. Ackers emphasizes in a changing and unsettled world the difficulty of forecasting the future of private enterprise, but produces strong arguments to show that for many years to come private woodlands should exist. He produces several reasons why private woodlands are not likely to be placed high on the list of industries to be nationalized. About the Dedication Scheme he feels that everyone who has the country's well-being at heart will welcome any just and wise control that will end the slaughter of immature woods and will rapidly decrease the area of unproductive woodland.

The advantage of dovetailing forestry and farm labour staffs for seasonal work is stressed. A wide range of special requirements is quoted to show the extent to which forestry meets

the requirements of agriculture and other industries. These requirements indicate that oak standards with hazel coppice are now an anachronism on private estates and should be replaced. With this emphasis on local requirements and conversion near the production areas it is claimed that a more sympathetic and appropriate integration of rural industries can be achieved than under any form of nationalized industry, and moreover, with beneficial effects on the mental and physical health of the rural community.

'The Application of the Working Plan to British Forestry' is the title of Mr. G. B. Ryle's contribution. It begins by stating that two wars have left British forestry physically at a low ebb, but that owing to a general awareness of this fact, forestry is now morally at a higher level than ever before. The recent forestry legislation has introduced a method of State control for private forestry which is both far-reaching and liberal in its concept—a statement which is more fully developed. The need for a Working Plan arises because it is necessary to ensure that the rules of good forestry are being followed, not only for the present but for the future as well. The success of the new forest policy, in which the State takes a close technical interest in private forestry for the first time, will depend on sympathetic co-operation between the relevant parties. The main requirement for the Dedication Scheme is that the plan of operations should be simple and follow the canons of sound management. For large woodlands, especially, there are obvious advantages in having a more elaborate Working Plan. The Working Plan needs of the Forestry Commission are examined, and the special case is clearly established for careful and more technical planning, now that the Commission's forests are passing more and more into the productive stage.

The Working Plan, in British forestry as a whole, is just coming into its own. A strong plea is made for the inclusion of full historical facts on many points, so that when a revision is made the compiler of the new plan will know the whole story.

J. J. M.

'Some Improved Techniques in Nurseries and on Planting Sites.' By J. J. MACGREGOR. Impl. Forestry Institute, Oxford, 1948. 1s. 2d., post free. (Reprinted from *Forestry Abstracts*, Vol. 10, No. 1, 1948.)

THE author lists no less than 64 references on the subject, and refers briefly to most of the outstanding recent developments. Owing to the high costs of modern labour, the machines and new techniques described are extremely important. The article and reprint are a valuable summary and source of references.

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